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## Four new species of *Simulium (Gomphostilbia)* (Diptera: Simuliidae) from Sarawak, Malaysia

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**Abstract:** Four new species of black flies, *Simulium (Gomphostilbia) kelabitense* sp. nov., *S. (G.) barioense* sp. nov., *S. (G.) paukatense* sp. nov., and *S. (G.) charlesi* sp. nov. are described from reared adult, pupal and mature larval specimens collected from Bario, Kelabit Highlands, Sarawak, Malaysia. *Simulium (G.) parahiyangum* Takaoka and Sigit is recorded for the first time from Sarawak. It is striking that *S. (G.) barioense* sp. nov. has the greater and varied number of pupal gill filaments (16 in female and 13 in male) and the much shortened cocoon.

Key words: black fly, Simuliidae, Sarawak, Malaysia, *Gomphostilbia*

The black fly fauna of Sarawak, Malaysia was poorly studied. Only eight species of the genus *Simulium* Latreille were reported, of which one was placed in the subgenus *Nevermannia*, three in the subgenus *Gomphostilbia*, and four in the subgenus *Simulium* (Smart and Clifford, 1969; Takaoka, 2001, 2008).

In September, 2007, I made an investigation on the pupae and larvae of black flies at seven stream sites in Kelabit Highlands in the northeastern part of Sarawak, as one of the six Japanese team members of the Research Programme on Diptera in Sarawak (representative, Prof. Emeritus Ichiro Miyagi) in collaboration with Sarawak Museum (representative, Dr. Charles Leh, M. U.), under the permission of Sarawak State Department of Forestry. In all, 10 species were collected, consisting of four known [*S. (G.) lehi* Takaoka, *S. (G.) parahiyangum* Takaoka and Sigit, *S. (G.) sheilae* Takaoka and Davies, and *S. (S.) keningauense* Takaoka] and six undescribed species, of which five belong to the subgenus *Gomphostilbia* and one to the subgenus *Simulium*. In this paper, four of the five undescribed species of the subge-

nus *Gomphostilbia* are described as new species on the basis of reared adults, pupae, and mature larvae. The remaining one undescribed species of the same subgenus, which is similar to *S. (G.) dentistylum* Takaoka and Davies described from Peninsular Malaysia (Takaoka and Davies, 1995), is represented only by three immature larvae and, therefore, is not described here. Among the four known species, *S. (G.) parahiyangum* is recorded from Sarawak for the first time.

The terms for morphological features used here follow those of Takaoka (2003). Holotype specimens of the new species are deposited at the Department of Infectious Disease Control, Faculty of Medicine, Oita University, Oita, Japan.

### *Simulium (Gomphostilbia) kelabitense* sp. nov.

**DESCRIPTION.** **Female.** Body length 2.8 mm. **Head.** Slightly narrower than width of thorax. Frons brownish-black, not shiny, densely covered with yellowish-white scale-like recumbent short hairs interspersed with several dark simple longer hairs along each

lateral margin; frontal ratio 1.61–1.71:1.00:3.16–3.34; frons-head ratio 1.00:6.04–6.45. Fronto-ocular area (Fig. 1A) well developed, narrow, directed dorsolaterally. Clypeus brownish-black, grayish-white pruinose, densely covered with yellowish-white scale-like recumbent short hairs interspersed with several dark longer hairs on each side. Labrum 0.57–0.61 times as long as clypeus. Antenna composed of scape, pedicel and 9 flagellomeres, medium brown except scape, pedicel, and base of 1st flagellomere whitish-yellow when viewed dorsally (1st to 5th or 6th flagellomeres mostly or partially whitish-yellow when viewed ventrally). Maxillary palp composed of 5 segments, light to medium brown, proportional lengths of 3rd, 4th, and 5th segments 1.00:1.04–1.11:2.78–3.16; 3rd segment (Fig. 1B) somewhat swollen; sensory vesicle (Fig. 1B) ellipsoidal, 0.23–0.26 times as long as 3rd segment, with medium-sized opening apically. Maxillary lacinia with 10–12 inner and 12 or 13 outer teeth. Mandible (Fig. 1C) with 23–26 inner and 8–10 outer teeth. Cibarium (Fig. 1D) medially forming rectangular sclerotized plate folded forward from posterior margin, with moderately sclerotized medial longitudinal ridge, and with pair of weakly sclerotized round plates between arms. **Thorax.** Scutum brownish-black (except anterior calli light brown), shiny, thinly grayish-white pruinose with 3 faint non-pruinose longitudinal vittae (1 medial and 2 submedial) when illuminated dorsally and viewed anteriorly or posteriorly, moderately covered with yellowish-white scale-like recumbent hairs interspersed with dark similar hairs along anterior margin. Scutellum dark brown, covered with yellowish-white short hairs and dark brown long upright hairs along posterior margin. Postnotum dark brown, slightly shiny, thinly grayish-white pruinose when viewed at certain angle of light, and bare. Pleural membrane bare. Katepisternum dark brown, longer than deep, shiny, moderately covered with dark hairs. **Legs.** Foreleg: coxa whitish-yellow; trochanter whitish-yellow to dark yellow; femur light brown with apical cap medium brown (though extreme tip narrowly pale); femur relatively densely covered with dark hairs submedially appearing to have submedial dark band; tibia medium brown with extreme base yellowish-white and medial portion of outer surface widely light brown; tarsus brownish-black,

with moderate dorsal hair crest; basitarsus moderately dilated, 6.25 times as long as its greatest width. Midleg: coxa light to medium brown except posterior surface brownish-black; trochanter yellow; femur light brown with basal 1/4 yellowish and apical cap medium brown (though extreme tip narrowly pale); femur relatively densely covered with dark hairs submedially appearing to have dark broad submedial band; tibia yellow on basal 2/5 with light brown subbasal spot on each lateral surface, and light to dark brown on apical 3/5; tibia densely covered with yellow fine hairs on basal 2/5 of outer surface and on 3/4 of inner surface (subbasal dark spots become hidden by these yellow hairs); tarsus dark brown except basal 1/2 or slightly more dark yellow. Hind leg: coxa yellow to light brown; trochanter yellow; femur light to medium brown with base yellow and apical cap dark brown (though extreme tip narrowly pale); tibia (Fig. 1E) yellow on little more than basal 2/5 with light to medium brown subbasal spot on each lateral surface, light brown on middle, and dark brown to brownish-black on apical 1/3; tibia densely covered with yellow fine hairs on basal 2/3 or more; tarsus (Fig. 1F) dark brown except basal 3/5 of basitarsus (though base dark brown) and basal 1/3 of 2nd tarsal segment whitish-yellow; basitarsus narrow, nearly parallel-sided, 6.55 times as long as wide, and 0.57 and 0.52 times as wide as greatest widths of tibia and femur, respectively; calcipala 1.3 times as long as wide, and about half as wide as greatest width of basitarsus. Claw (Fig. 1G) with large basal tooth 0.51 times as long as claw. **Wing.** Length 2.5 mm. Costa with dark spinules and hairs except basal portion with yellow hairs. Subcosta with dark hairs except near apex bare. Hair tuft on stem vein mostly yellow. Basal portion of radius fully haired; R<sub>1</sub> with dark spinules and hairs; R<sub>2</sub> with hairs only. Basal cell absent. **Abdomen.** Basal scale dark yellow, with fringe of whitish-yellow hairs. Dorsal surface of abdomen light brown to brownish-black except basal 1/2 of segment 2 dark yellow, moderately covered with dark short to long hairs; tergites of segments 2 and 6–9 wide and shiny, while those of segments 3–5 narrow, nearly quadrate, subequal in shape and size to one another, and all dull; ventral surface of segment 2 entirely pale whitish-yellow, and those of other segments light to

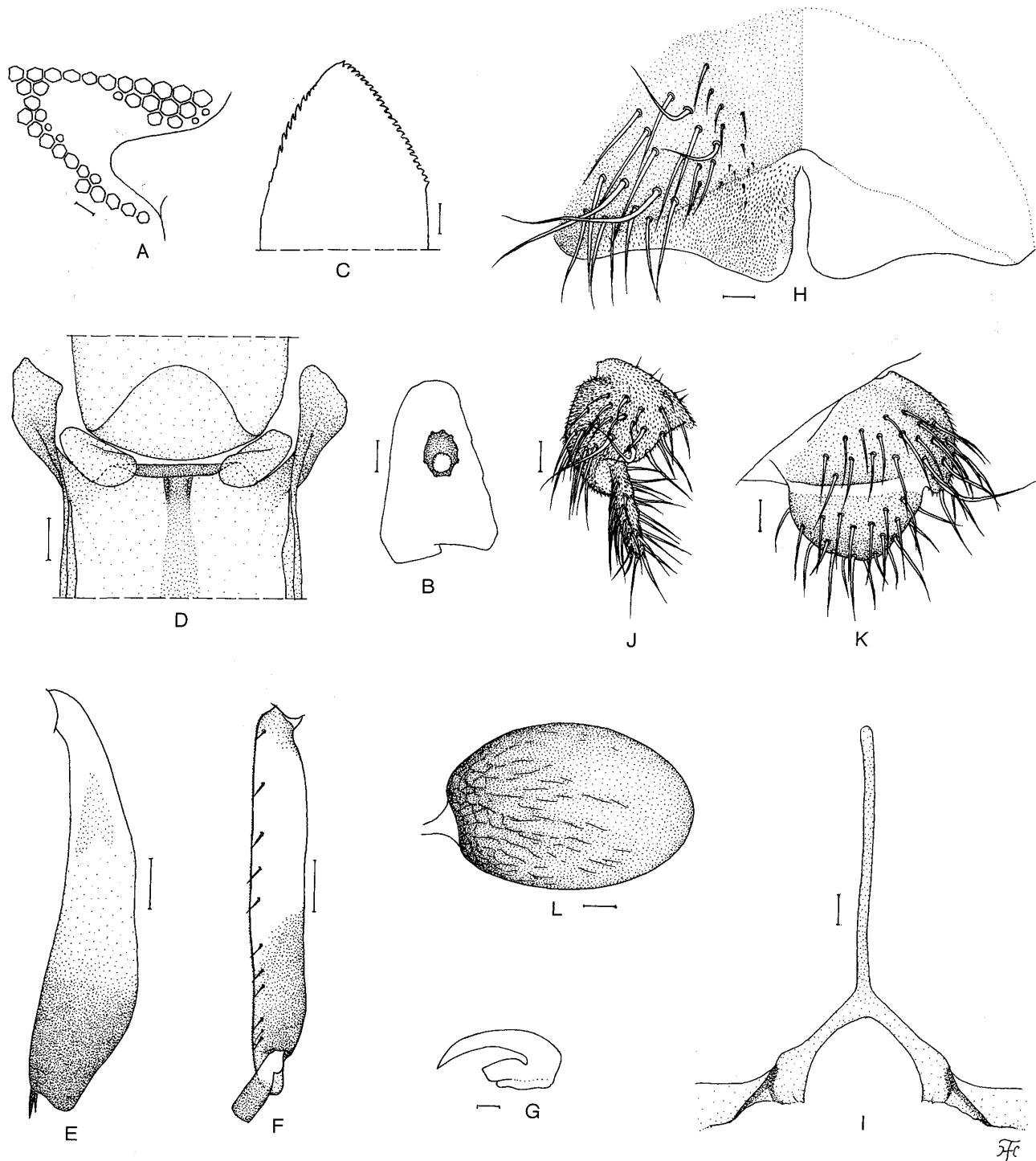


Fig. 1. Female of *Simulium (Gomphostilbia) kelabitense* sp. nov. A, fronto-ocular area (right side); B, 3rd segment of maxillary palp with sensory vesicle (right side and front view); C, mandible; D, cibarium; E, hind tibia (left side and outer view); F, basitarsus and 2nd tarsal segment of hind leg showing calcipala and pedisulcus (left side and outer view); G, claw; H, sternite 8 and ovipositor valves *in situ* (ventral view); I, genital fork (ventral view); J and K, paraprocts and cerci *in situ* (right side; J, ventral view; K, lateral view); L, spermatheca (lateral view). Scale bars. 0.1 mm for E and F; 0.02 mm for A, B, D and H-L; 0.01 mm for C and G.

medium brown; sternal plate on segment 7 un-developed. **Genitalia.** Sternite 8 (Fig. 1H) bare medially, with 24–30 medium-long to very long hairs together with a few to several short

slender hairs on each side. Ovipositor valves (Fig. 1H) triangular, with round medioposterior corners, thin, membranous, moderately covered with microsetae interspersed with 1 or

2 short setae; inner margins very slightly sinuous, slightly sclerotized, and moderately separated from each other. Genital fork (Fig. 1I) of usual inverted-Y form, with arms of moderate width; arm moderately folded medially. Paraproct in ventral view (Fig. 1J) nearly triangular, pointed medially, and with 4 or 5 sensilla on anteromedial surface; paraproct in lateral view (Fig. 1K) somewhat produced ventrally, 0.76 times as long as wide, with 24–30 medium-long to long hairs on ventral and lateral surfaces. Cercus in lateral view (Fig. 1K) short, rounded posteriorly, 0.57 times as long as wide. Spermatheca (Fig. 1L) ellipsoidal, 1.39–1.46 times as long as its greatest width, well sclerotized except duct and small area near juncture with duct unsclerotized, and with many fissures on surface; internal setae absent; both accessory ducts slender, slightly larger in diameter than major one.

**Male.** Body length 2.8–3.1 mm. **Head.** Wider than thorax. Upper eye consisting of 12 vertical columns and 13 horizontal rows of large facets. Face dark brown, grayish pruinose. Clypeus dark brown, densely covered with yellow scale-like short to medium-long hairs (mostly directed upwards) interspersed with several dark brown simple longer hairs near lower margin. Antenna composed of scape, pedicel and 9 flagellomeres, yellow except apex of 9th flagellomere somewhat darkened; 1st flagellomere elongate, 1.69–1.88 times as long as 2nd flagellomere. Maxillary palp with 5 segments, light brown, proportional lengths of 3rd, 4th, and 5th segments 1.00 : 1.10–1.13 : 2.75; 3rd segment (Fig. 2A) widened apically; sensory vesicle (Fig. 2A) nearly globular or ellipsoidal, 0.16–0.21 times as long as 3rd segment, and with medium-sized opening. **Thorax.** Scutum medium brown, with 3 dark brown narrow longitudinal vittae (1 medial and 2 submedial) united to dark brown prescutellar area, shiny, and densely covered with golden yellow short hairs; scutellum light brown, with golden yellow short hairs and dark brown long upright hairs along posterior margin. Postnotum medium brown, gray pruinose narrowly along anterior margin and slightly shiny when illuminated at certain angle of light, and bare. Pleural membrane bare. Katepisternum medium brown, longer than deep, moderately covered with dark short hairs. **Legs.** Color nearly as in female except mid tibia yellow on basal 1/4 and without dark

subbasal spot, and hind tibia (Fig. 2B) with no or faint subbasal spot on each side, and hind basitarsus (Fig. 2C) whitish-yellow on little more than basal 1/2. Fore basitarsus moderately dilated, 7.9 times as long as its greatest width; hind basitarsus (Fig. 2C) narrow, nearly parallel-sided, 6.00 times as long as wide, and 0.57 and 0.59 times as wide as greatest widths of tibia and femur, respectively; calcipala nearly as long as its basal width, and 0.53 times as wide as greatest width of basitarsus. **Wing.** Length 2.3 mm. Costa with dark spinules and hairs except basal portion with golden yellow hairs. Subcosta bare. Hair tuft on stem vein golden yellow. Basal portion of radius fully haired;  $R_1$  with dark spinules and hairs;  $R_2$  with hairs only. Basal cell absent. **Abdomen.** Basal scale dark yellow, with fringe of yellow hairs. Dorsal surface of 2nd segment yellow except narrow area along posterior margin light brown, moderately covered with golden yellow hairs; that of remaining segments medium brown to brownish-black, covered with dark short to long hairs except segment 3 with golden yellow hairs as well as dark hairs; segments 2 and 5–8 each with pair of shiny whitish-gray pruinose dorsolateral patches, of which those on segment 2 broadly connected in middle to each other, and those on segments 5–7 narrowly connected to each other along anterior margin; in addition, segments 3 and 4 shiny narrowly along anterior margin of dorsal surface and segment 8 shiny on each lateral surface when illuminated at certain angle of light. **Genitalia.** Coxite in ventral view (Fig. 2D) nearly rectangular, 1.8 times as long as its greatest width. Style in ventral view (Fig. 2D) slender, tapered toward apex, 0.8 times as long as coxite, gently bent inward, with apical spine; style in ventrolateral view (Fig. 2E) very slightly narrowed from base to apical 1/3, then abruptly tapered toward apex. Ventral plate in ventral view (Fig. 2D) with body transverse, 0.56–0.58 times as long as wide, nearly parallel-sided or slightly narrowed posteriorly, with anterior margin produced anteromedially, and posterodorsal margin slightly convex medially, and densely covered with microsetae on ventral surface; basal arms of moderate length, nearly parallel-sided; ventral plate in lateral view (Fig. 2F) much produced ventrally; ventral plate in end view (Fig. 2G) rounded ventrally, and densely covered with microsetae on posterior surface. Median sclerite (Fig. 2D)

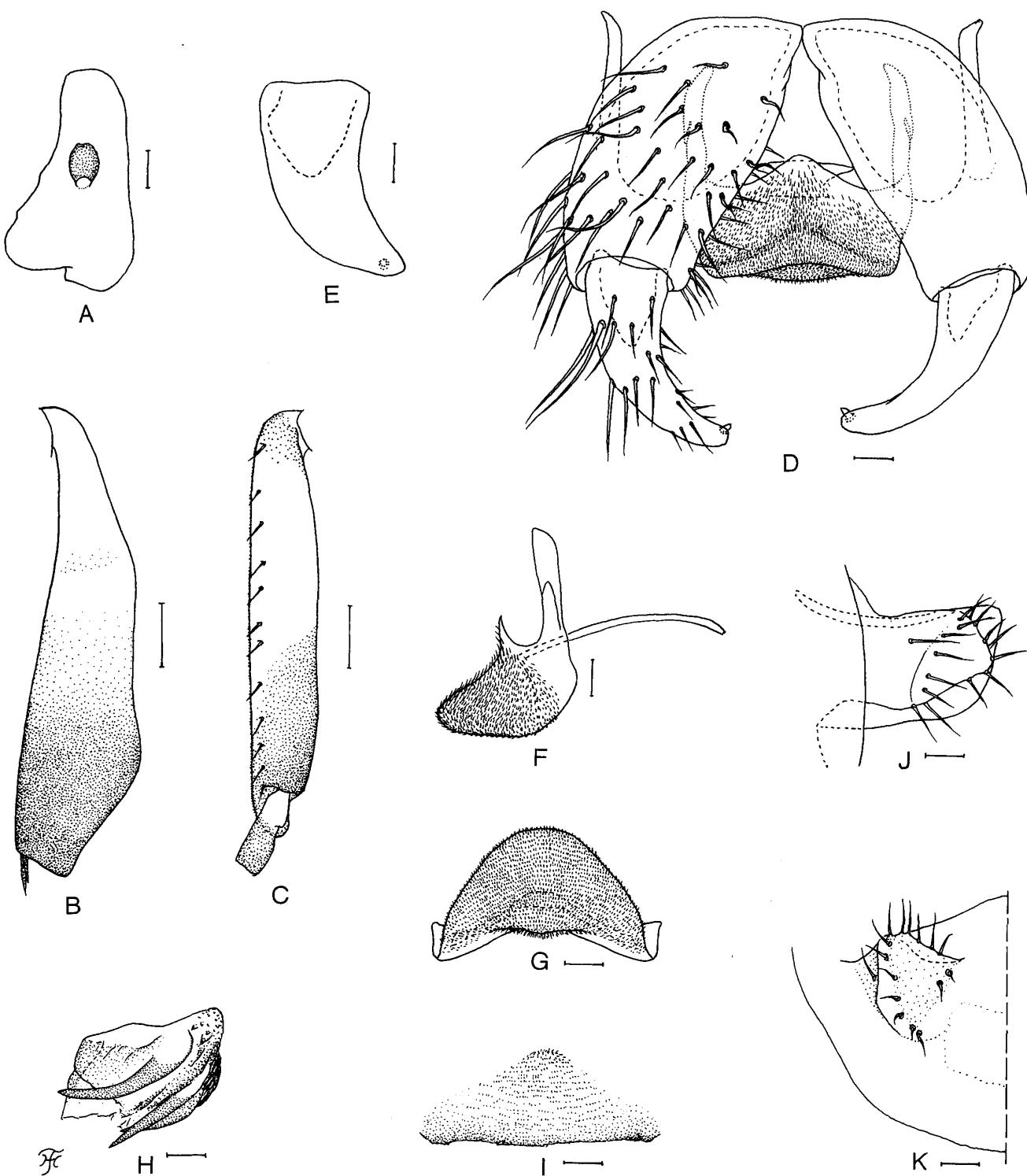


Fig. 2. Male of *Simulium (Gomphostilbia) kelabitense* sp. nov. A, 3rd segment of maxillary palp with sensory vesicle (left side and front view); B, hind tibia (left side and outer view); C, basitarsus and 2nd tarsal segment of hind leg showing calcipala and pedisulcus (left side and outer view); D, coxites, styles, ventral plate and median sclerite *in situ* (ventral view); E, style (right side and ventrolateral view); F, ventral plate and median sclerite (lateral view); G, ventral plate (end view); H, paramere (right side and end view); I, aedeagal membrane with dorsal plate (end view); J and K, 10th abdominal segments and cerci (J, right side and lateral view; K, right side and end view). Scale bars. 0.1 mm for B and C; 0.02 mm for A and D-K.

thin, plate-like, wide, and connected to ventral plate far from anterior margin. Paramere (Fig. 2H) of moderate size, each with 3 distinct long and stout hooks and several smaller ones close together near apex. Aedeagal membrane (Fig. 2H) moderately setose; dorsal plate (Fig. 2I) weakly sclerotized. Abdominal segment 10 (Fig. 2J, K) without distinct hairs near posterior margin on ventral surface and with 0 or 1 hair on each side. Cercus (Fig. 2J, K) triangular, encircled with 13–15 hairs.

**Pupa.** Body length 2.8–3.2 mm. **Head.** Integument yellow to yellowish-brown, moderately covered with small round tubercles on frons and each lateral surface but bare on antennal sheath and underside of face; antennal sheath without any protuberances; face with pair of simple very long trichomes with uncoiled apices, and frons with 3 pairs of simple very long trichomes with uncoiled apices; 3 frontal trichomes on each side arising close together, subequal in length to one another and slightly longer than facial one. **Thorax.** Integument yellow to yellowish-brown, moderately covered with round tubercles, with 3 simple very long trichomes with coiled or uncoiled apices dorsomedially, 2 simple trichomes with uncoiled apices (1 long and 1 very long) anterolaterally, 1 simple long trichome with uncoiled apex posterolaterally, and 3 simple trichomes with uncoiled apices (1 long, 1 medium-long and 1 short) ventrolaterally on each side. Gill (Fig. 3A) composed of 8 slender thread-like filaments, nearly as long as pupal body, arranged in  $[(2+1)+(1+2)]+2$  filaments from dorsal to ventral, with somewhat swollen transparent organ ventrally (partially broken) at base; upper and middle triplets sharing very short stalk arising from short common basal stalk; upper triplet composed of 1 individual and 2 paired filaments with very short stalk; middle triplet composed of 1 individual and 2 paired filaments with short stalk, or rarely 3 individual filaments arising at same level; stalk of ventral paired filaments of medium length, slightly thinner than interspiracular trunk, and 1.2 times as thick as primary stalks of middle and dorsal triplets; stalk of upper triplet lying against that of lower pair nearly at angle of 80 degrees when viewed laterally; all filaments light brown, gradually tapered toward apex, subequal in length and thickness to one another except outer filament (2.8–3.2 mm long) of ventral pair 1.4 times as long as and 1.7

times as thick as other filaments (2.0–2.3 mm long); cuticle of all filaments with well marked annular ridges and furrows though becoming less marked apically, densely covered with minute tubercles. **Abdomen.** Dorsally, segments 1 and 2 light brown and smooth; segment 1 with 1 simple slender medium-long hair-like seta on each side; segment 2 with 1 simple slender medium-long hair-like seta and 5 very short somewhat spinous setae, submedially on each side; segments 3 and 4 each with 4 hooked spines and 1 very short somewhat spinous seta on each side; segment 5 lacking dorsal spine-combs; segments 6–9 each with spine-combs in transverse row (though spine-combs on segment 9 somewhat smaller than those on other segments), together with comb-like groups of minute spines on each side; segment 9 with pair of distinct flat plate-like terminal hooks extending laterally at base and having weakly serrate or undulate outer margin (Fig. 3B). Ventrally, segment 4 with 1 simple hook and few simple slender very short setae on each side; segment 5 with pair of bifid hooks submedially and few very short simple slender setae on each side; segments 6 and 7 each with pair of bifid inner and simple outer hooks somewhat spaced from each other and few very short simple slender setae on each side; segments 4–8 with comb-like groups of minute spines. Each side of segment 9 with 3 grapnel-shaped hooklets. **Cocoon** (Fig. 3C). Wall-pocket-shaped or shoe-shaped, thinly and neatly woven, extending ventrolaterally; anterodorsal margin somewhat thickly woven, and anterolateral margins extending forward and inward, often connected weakly to each other ventrally, and in some cocoons, even forming low anteroventral collar; posterior 1/2 with floor moderately woven; individual threads visible; 3.5–4.5 mm long by 2.0–3.2 mm wide.

**Mature larva.** Body length 5.2–6.0 mm. Body whitish to light grayish; most larvae with faint to distinct reddish-brown transverse band on ventral surface of abdominal segment 7; some larvae with reddish-brown marking on each lateral surface of abdominal segments 4 and 5 or only of segment 5; few larvae with reddish-brown marking on each dorsolateral surface of abdominal segment 8. Cephalic apotome yellowish though somewhat darkened on posterior 1/2, in particular in front of posterior margin; head spots positive, faintly to moderately darkened though posterolateral

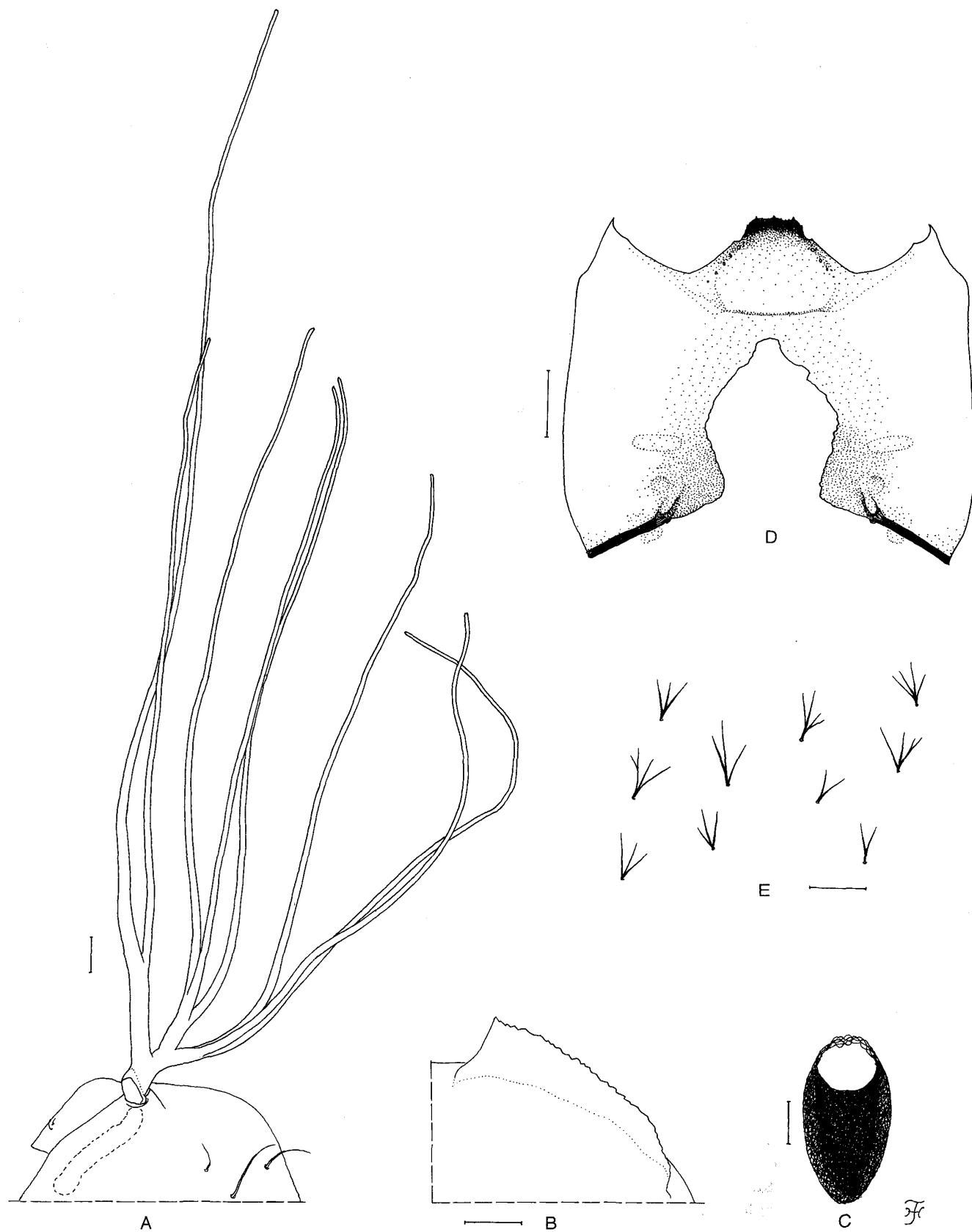


Fig. 3. Pupa and mature larva of *Simulium (Gomphostilbia) kelabitense* sp. nov. A-C: pupa, and D and E: larva. A, gill filaments and anterior part of thoracic integument (left side and outer view); B, terminal hook (right side and end view); C, cocoon (dorsal view); D, head capsule showing postgenal cleft (ventral view); E, dark branched setae on dorsal surface of abdominal segment 8 *in situ*. Scale bars. 1.0 mm for C; 0.1 mm for A and D; 0.02 mm for B and E.

spots merged into dark background color or even appearing negative in most larvae, and anterior mediolongitudinal spot indistinct in some larvae. Lateral surface of head capsule yellowish except eye-spot region whitish and large area between eye-spot region and posterior margin darkened; eyebrow well defined, moderately darkened; small isolated spot below eye-spot region faintly or moderately darkened. Ventral surface of head capsule (Fig. 3D) yellowish except medial portion along lateral margins of postgenal cleft widely darkened; transverse spot on each side of postgenal cleft positive, moderately darkened. Antenna composed of 3 segments and apical sensillum, somewhat longer than stem of labral fan; proportional lengths of 1st, 2nd, and 3rd segments 1.00 : 0.96 : 0.83–1.04; antenna pale except dorsal surface of 1st segment much darkened. Labral fan with 30–32 main rays. Mandible with 1st comb-tooth much longer than 2nd comb-tooth, which is slightly longer than 3rd one; mandibular serration composed of 2 teeth (1 medium-sized and 1 small); major tooth at acute angle against mandible on apical side; supernumerary serrations absent. Hypostoma with row of 9 apical teeth; median and each corner tooth prominent, subequal in length to each other, and much longer than 3 intermediate teeth on each side; lateral margin smooth; 4 or 5 hypostomal bristles per side, lying subparallel to lateral margin. Postgenal cleft (Fig. 3D) arrow-head shaped, moderately constricted basally, widest medially, pointed apically, deep, 6.83–8.40 times as long as postgenal bridge. Cervical sclerite composed of 2 yellow slender rod-like pieces, not fused to occiput, widely separated medially from each other. Thoracic cuticle bare. Abdominal cuticle almost bare on segments 1–4 and moderately to densely covered with dark simple and branched minute setae each with 2–6 branches (mostly 2–4 branches, Fig. 3E) on dorsal and dorsolateral surfaces of segments 5–8, and also moderately covered with simple colorless minute setae on each side of anal sclerite of last segment. Rectal scales apparently absent. Rectal papilla compound, each of 3 lobes with 10–15 finger-like secondary lobules. Anal sclerite of usual X-form, with anterior arms very slightly shorter than posterior ones, broadly sclerotized at base; accessory sclerite absent; basal juncture area with 0–3 sensilla medially. Last abdominal segment expanded

ventrolaterally forming double bulges on each side, visible as large conical ventral papilla when viewed from side. Posterior circlet with 84–86 rows of up to 14 hooklets per row.

**TYPE SPECIMENS.** Holotype female (with associated pupal exuviae and cocoon) reared from pupa (preserved in 80% ethanol), collected from a small stream (width 0.3–1.0 m, water temperature 20.0°C, shaded, altitude about 1,000 m) slowly flowing in a natural forest near a quarry, near the road from Bario to Pa Ukat, Bario, Sarawak, Malaysia, 1. IX. 2007, by H. Takaoka. Paratypes: 5 females, 13 males (all with associated pupal exuviae and cocoons), and 5 mature larvae, same data as those of the holotype.

**ECOLOGICAL NOTES.** The pupae and larvae of this new species were collected from tree leaves in the water of a moderately flowing small stream. Associated species were *S. (G.) barioense* sp. nov., *S. (G.) paukatense* sp. nov. and *S. (G.) sheilae*.

**ETYMOLOGY.** The species name *kelabitense* refers to Kelabit Highlands, where this new species was collected.

**REMARKS.** According to the key (Takaoka, 2003), *S. (G.) kelabitense* sp. nov. is readily assigned to the *batoense* species-group within the subgenus *Gomphostilbia* by having the adult antenna with 11 segments, pleural membrane bare, female claw with a large basal tooth (Fig. 1G) and male hind basitarsus not enlarged (Fig. 2C), and eight gill filaments (Fig. 3A).

This new species is characterized by the male antenna almost yellow with the apex darkened, and the pupal gill with eight filaments, of which the outer filament of the ventral pair is 1.4 times as long as the other seven filaments (Fig. 3A). This new species appears to be very closely related to *S. (G.) cheongi* Takaoka and Davies described from Peninsular Malaysia (Takaoka and Davies, 1995) by sharing many characteristics. However there are differ-

ences in several features between the two species including the relative length of the sensory vesicle against the female third maxillary palpal segment (0.23–0.26 vs 0.3), the number of the hairs on the ventral and lateral surface of the paraproct (24–30 vs 10), the number of male large upper eye-facets (12 vertical columns and 13 horizontal rows vs 10 vertical columns and 11 horizontal rows), the relative length of the outer filament of the ventral pair against the other filaments (1.4 vs little less than 2.0). The pupa of *S. (G.) rayohense* Smart and Clifford from Sabah (Smart and Clifford, 1969) has the similar arrangement of the gill filaments but the male of this known species is easily distinguished by the shape of the ventral plate, of which both lateral margins are convex, not parallel-sided as in *S. (G.) kelabitense* sp. nov.

***Simulium (Gomphostilbia) barioense***  
sp. nov.

**DESCRIPTION. Female.** Body length 1.9 mm. **Head.** Slightly narrower than width of thorax. Frons brownish-black, slightly shiny when illuminated at certain angle of light, densely covered with whitish-yellow scale-like recumbent short hairs interspersed with several dark simple longer hairs along each lateral margin; frontal ratio 1.74 : 1.00 : 2.59; frons-head ratio 1.00 : 4.81. Fronto-ocular area (Fig. 4A) well developed, narrow, directed dorsolaterally. Clypeus brownish-black, slightly shiny when illuminated at certain angle of light, densely covered with whitish-yellow scale-like recumbent short hairs interspersed with several dark longer hairs on each side. Labrum 0.74 times as long as clypeus. Antenna composed of scape, pedicel and 9 flagellomeres, medium brown except scape, pedicel, and base of 1st flagellomere yellow; 1st flagellomere more widely yellow up to basal 1/2 when viewed laterally. Maxillary palp composed of 5 segments, light to medium brown, proportional lengths of 3rd, 4th, and 5th segments 1.00 : 1.14 : 2.31; 3rd segment (Fig. 4B) somewhat swollen; sensory vesicle (Fig. 4B) ellipsoidal, 0.31 times as long as 3rd segment, with medium-sized opening apically. Maxillary lacinia with 12 or

13 inner and 13 or 14 teeth. Mandible (Fig. 4C) with 20 or 21 inner and no outer teeth. Cibarium (Fig. 4D) medially forming rectangular sclerotized plate folded forward from posterior margin, with strongly sclerotized medial longitudinal ridge. **Thorax.** Scutum medium-brown (except anterior calli light brown) with 3 dark brown longitudinal vittae (1 medial and 2 submedial) all connected to dark brown prescutellar area, shiny, thinly grayish-white pruinose when illuminated at certain angle of light, densely covered with whitish-yellow scale-like recumbent hairs. Scutellum ochreous with central portion dark brown, covered with whitish-yellow short hairs and dark brown long upright hairs along posterior margin. Postnotum dark brown with central portion light brown, slightly shiny, thinly grayish-white pruinose when viewed at certain angle of light, and bare. Pleural membrane bare. Katepisternum dark brown, longer than deep, shiny, moderately covered with dark hairs as well as pale ones. **Legs.** Foreleg: coxa whitish-yellow; trochanter dark yellow with base whitish-yellow; femur dark yellow to light brown with apical cap medium brown (though extreme tip narrowly pale); tibia light brown with base whitish-yellow, median portion on outer surface dark yellow, and little less than apical 1/3 medium brown; tarsus brownish-black, with moderate dorsal hair crest; basitarsus moderately dilated, 6.17 times as long as its greatest width. Midleg: coxa medium brown except posterior surface brownish-black; trochanter yellow; femur yellow with apical cap light brown (though extreme tip pale); femur relatively densely covered with dark hairs submedially on outer surface appearing to have dark broad submedial band; tibia yellow on little less than basal 1/3 with dark yellow subbasal spot on each lateral surface, and dark brown on little more than apical 2/3 (though tibia yellow on basal 1/2 or little more on inner surface); tarsus dark brown except little more than basal 1/2 and base of 2nd segment dark yellow. Hind leg: coxa yellow except narrowly darkened along basal margin; trochanter yellow; femur dark yellow with apical cap light to medium brown (though extreme tip narrowly pale); tibia (Fig. 4E) yellow on little more than basal 2/3 with light brown subbasal spot on each lateral surface, and dark brown to brownish-black on rest; tibia densely covered with yellow fine hairs on

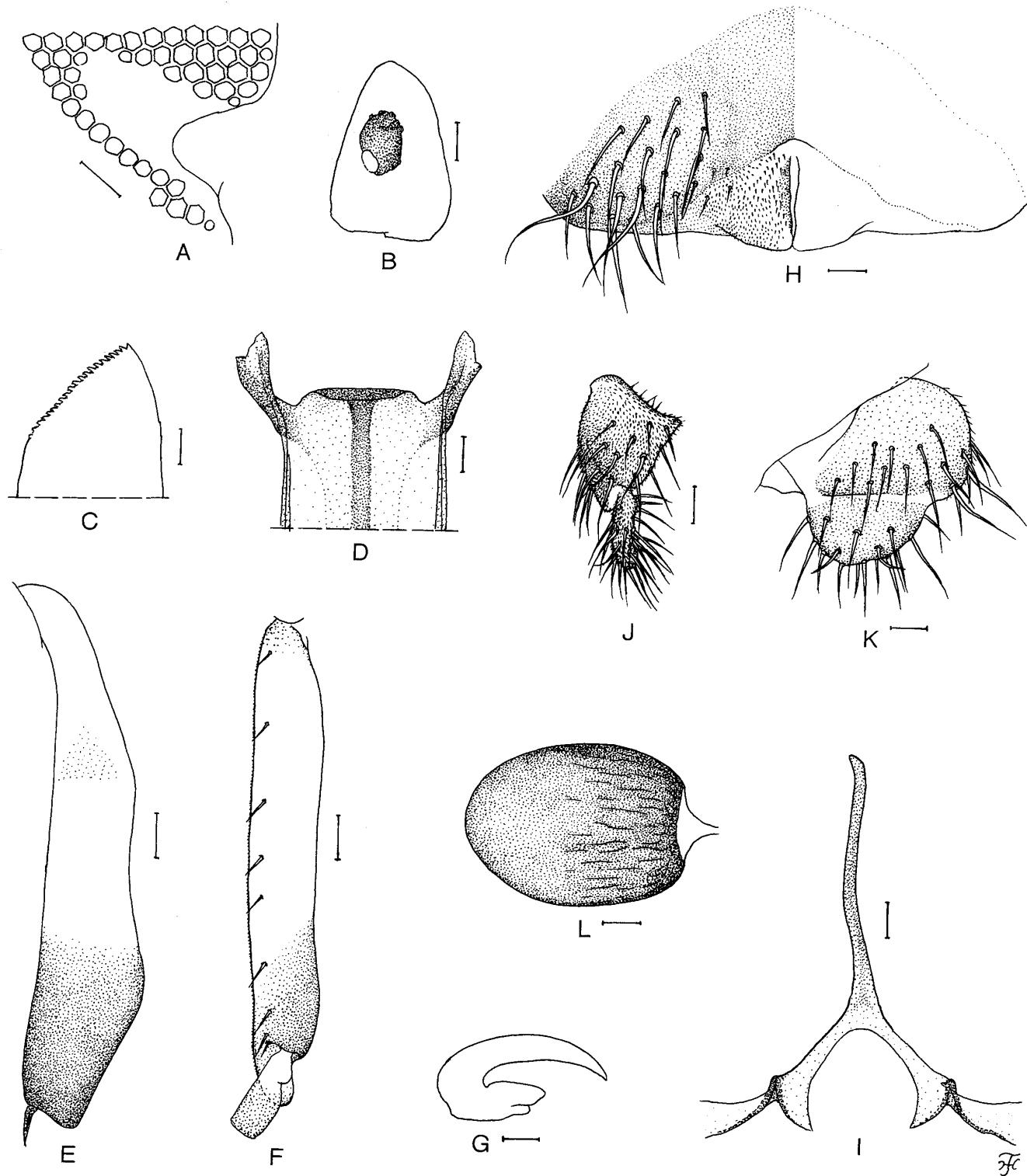


Fig. 4. Female of *Simulium (Gomphostilbia) barioense* sp. nov. A, fronto-ocular area (right side); B, 3rd segment of maxillary palp with sensory vesicle (left side and front view); C, mandible; D, cibarium; E, hind tibia (left side and outer view); F, basitarsus and 2nd tarsal segment of hind leg showing calcipala and pedisulcus (left side and outer view); G, claw; H, sternite 8 and ovipositor valves *in situ* (ventral view); I, genital fork (ventral view); J and K, paraprocts and cerci *in situ* (right side; J, ventral view; K, lateral view); L, spermatheca (lateral view). Scale bars. 0.05 mm for E and F; 0.04 mm for A; 0.02 mm for B, D and H-L; 0.01 mm for C and G.

basal 2/3 or more; tarsus dark brown to brownish-black except little more than basal 2/3 of basitarsus (though base medium brown) and little less than basal 1/2 of 2nd tarsal segment whitish-yellow; basitarsus (Fig. 4F) narrow, nearly parallel-sided, 6.40 times as long as wide, and 0.63 and 0.51 times as wide as greatest widths of tibia and femur, respectively; calcipala 1.21 times as long as basal width, and 0.56 times as wide as greatest width of basitarsus. Claw (Fig. 4G) with large basal tooth 0.50 times as long as claw. **Wing.** Length 2.0 mm. Costa with dark spinules and hairs except basal portion with yellow hairs. Subcosta with dark hairs except near apex bare. Hair tuft on stem vein mostly yellow. Basal portion of radius fully haired;  $R_1$  with dark spinules and hairs;  $R_2$  with hairs only. Basal cell absent. **Abdomen.** Basal scale yellow, with fringe of yellow hairs. Dorsal surface of abdomen light to dark brown except segment 2 yellow, moderately covered with dark short to long hairs; tergites of segments 2 and 6–9 wide and shiny, while those of segments 3–5 narrow, nearly quadrate, subequal in shape and size to one another, and all dull; ventral surface yellow except segment 8 dark brown; sternal plate on segment 7 undeveloped. **Genitalia.** Sternite 8 (Fig. 4H) bare medially, with 18 or 19 medium-long to very long hairs together with few short slender hairs on each side. Ovipositor valves (Fig. 4H) triangular, with round medioposterior corners, thin, membranous, moderately covered with microsetae interspersed with 1 or 2 short setae; inner margins very slightly sinuous, slightly sclerotized, and moderately separated from each other. Genital fork (Fig. 4I) of usual inverted-Y form, with arms of moderate width; arm moderately folded medially, with triangular lobe directed medioposteriorly. Paraproct in ventral view (Fig. 4J) nearly triangular, pointed medially, and with 5 sensilla on anteromedial surface; paraproct in lateral view (Fig. 4K) somewhat produced ventrally, 0.81 times as long as wide, with 18 or 19 medium-long to long hairs on ventral and lateral surfaces. Cercus in lateral view (Fig. 4K) short, rounded posteriorly, 0.55 times as long as wide, with several short to medium-long hairs on outer surface. Spermatheca (Fig. 4L) ellipsoidal, 1.34 times as long as its greatest width, well sclerotized except duct and area near juncture with duct unsclerotized, and with many fis-

sures on surface of basal 1/2; internal setae absent; both accessory ducts slender, subequal in diameter to major one.

**Male.** Body length 2.0–2.1 mm. **Head.** Much wider than thorax. Upper eye consisting of 10 or 11 vertical columns and 11 or 12 horizontal rows of large facets. Face dark brown, grayish pruinose. Clypeus dark brown, densely covered with yellow scale-like short to medium-long hairs (mostly directed upwards) interspersed with several dark brown simple longer hairs near lower margin. Antenna composed of scape, pedicel and 9 flagellomeres, dark yellow with scape, pedicel and base of 1st flagellomere pale yellow and apical 3 or 4 flagellomeres medium brown; 1st flagellomere moderately elongate, 1.60 times as long as 2nd flagellomere. Maxillary palp with 5 segments, light brown, proportional lengths of 3rd, 4th, and 5th segments 1.00 : 1.19 : 2.93; 3rd segment (Fig. 5A) widened apically; sensory vesicle (Fig. 5A) nearly globular or ellipsoidal, 0.26 times as long as 3rd segment, and with medium-sized opening. **Thorax and Legs.** Color and hair covering similar to those of female except subbasal band of mid and hind tibiae indistinct or only slightly discernible (Fig. 5B). Fore basitarsus moderately dilated, 6.94 times as long as its greatest width; hind basitarsus (Fig. 5C) narrow, nearly parallel-sided, 5.77 times as long as wide, and 0.63 and 0.57 times as wide as greatest widths of tibia and femur, respectively; calcipala 1.17 times as long as its basal width, and 0.54 times as wide as greatest width of basitarsus. **Wing.** Length 1.7 mm. Other features as in female except subcosta bare.

**Abdomen.** Basal scale dark yellow, with fringe of yellow hairs. Dorsal surface of abdominal segments medium brown to brownish-black except entire surface of 2nd segment and most of 3rd segment yellow, moderately covered with dark hairs as well as yellow ones; segments 2 and 5–8 each with pair of shiny dorsolateral or lateral patches. **Genitalia.** Coxite in ventral view (Fig. 5D) nearly rectangular, about 1.8 times as long as its greatest width. Style in ventral view (Fig. 5D) slender, tapered toward apex, 0.85 times as long as coxite, gently bent inward, with apical spine; style in ventrolateral view (Fig. 5E) gradually narrowed from base to apex. Ventral plate in ventral view (Fig. 5D) with body transverse, 0.58 times as long as wide, narrowed posteriorly from middle to posterior margin,

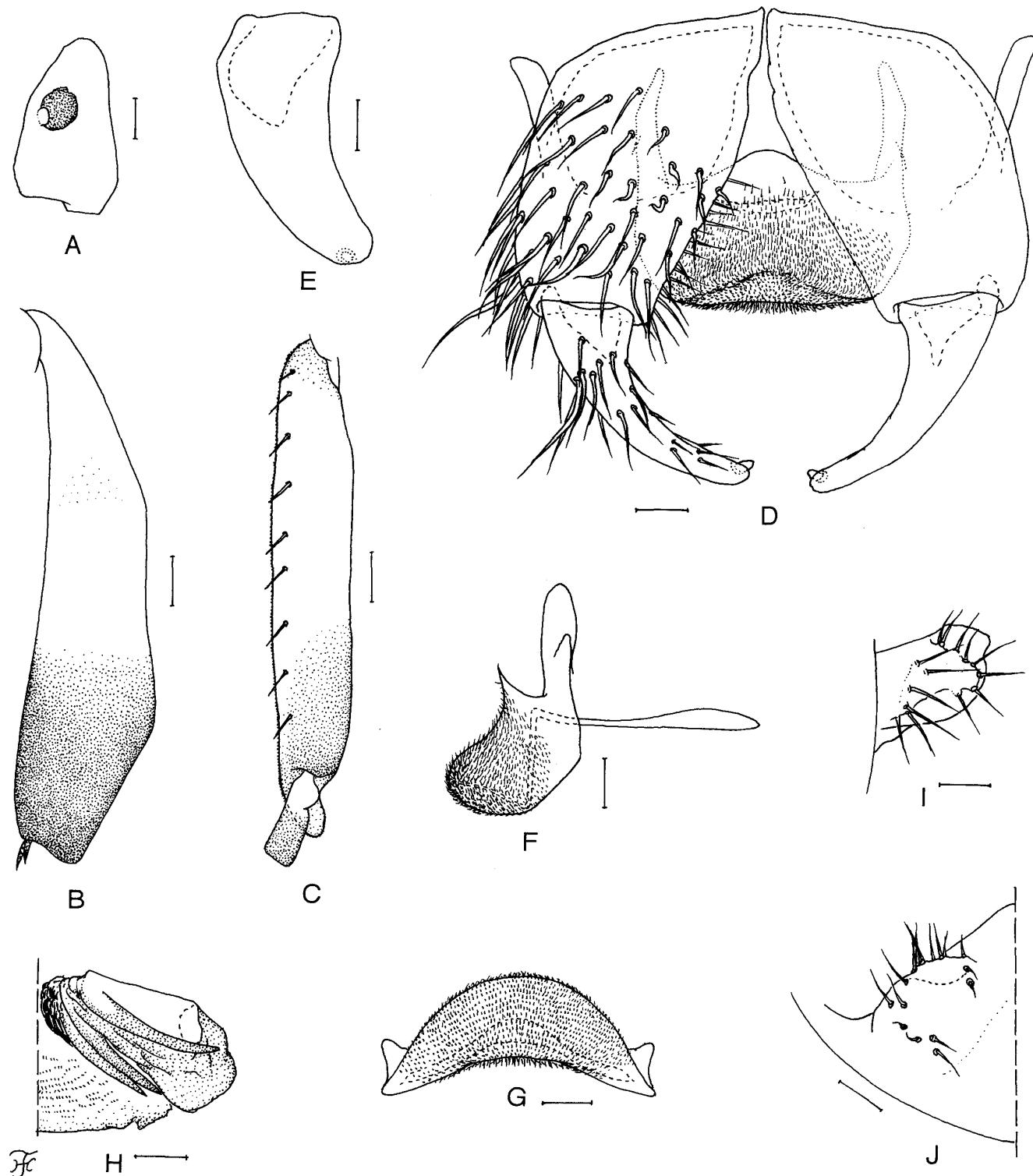


Fig. 5. Male of *Simulium (Gomphostilbia) barioense* sp. nov. A, 3rd segment of maxillary palp with sensory vesicle (left side and front view); B, hind tibia (left side and outer view); C, basitarsus and 2nd tarsal segment of hind leg showing calcipala and pedisulcus (left side and outer view); D, coxites, styles, ventral plate *in situ* (ventral view); E, style (right side and ventrolateral view); F, ventral plate and median sclerite (lateral view); G, ventral plate (end view); H, paramere and aedeagal membrane with dorsal plate (left side and end view); I and J, 10th abdominal segments and cerci (I, right side and lateral view; J, right side and end view). Scale bars. 0.05 mm for B and C; 0.02 mm for A and D-J.

with anterior margin produced anteromedially, and posterodorsal margin nearly straight, and densely covered with microsetae on ventral surface; basal arms of moderate length, nearly parallel-sided; ventral plate in lateral view (Fig. 5F) much produced ventrally; ventral plate in end view (Fig. 5G) rounded ventrally, and densely covered with microsetae on posterior surface. Median sclerite (Fig. 5D, F) thin, plate-like, wide, and connected to ventral plate far from anterior margin. Paramere (Fig. 5H) of moderate size, each with 3 distinct long and stout hooks and several smaller ones close together near apex. Aedeagal membrane (Fig. 5H) moderately setose; dorsal plate weakly sclerotized. Abdominal segment 10 (Fig. 5I, J) without distinct hairs near posterior margin on ventral and lateral surface. Cercus (Fig. 5I, J) small, round, encircled with 15 hairs.

**Pupa.** Body length 2.5 mm. **Head.** Integument yellow, moderately covered with small round tubercles on frons and each lateral surface but bare on antennal sheath and on underside of face; antennal sheath without any protuberances; frons with 3 pairs of simple very long trichomes with uncoiled apices; 3 frontal trichomes on each side arising close together, subequal in length to one another; face with pair of simple long trichomes with uncoiled apices. **Thorax.** Integument yellow, moderately covered with round tubercles, with 3 trichomes (arising close together) dorsomedially, 2 trichomes anterolaterally, with 1 trichome posterolaterally, 3 trichomes (arising close together) ventrolaterally, and 2 trichomes (arising close together) below base of gill (Fig. 6B), on each side, all simple and medium-long to long. Gill (Fig. 6A) composed of 13 (in male) or 16 (in female) thread-like filaments arranged in 3 groups (dorsal, middle and ventral); all 3 groups arising at almost same level from short common basal stalk; dorsal group composed of 2 paired and 1 individual filaments (2+1), with very short common stalk directed upwardly in male (Fig. 6A, B); dorsal group composed of 2 paired and 4 individual filaments (2+1+1+1+1) arising upwardly from somewhat raised base of dorsal surface in female (Fig. 6C); middle group composed of 4 individual and 2 paired filaments (1+1+1+1+2) or 2 individual and 4 paired filaments (1+2+2+1), and with very short common stalk directed medially and forwardly; ventral group composed of 4 paired filaments (2+2 as shown in

Fig. 6B) or 2 individual and 2 paired filaments [1+2+1 as shown in Fig. 6C, or 1+(2+1) as shown in Fig. 6A], and with short to medium-long stalk directed outwardly and forward; gill with somewhat swollen transparent organ ventrally (partially broken) at base; all filaments light brown, subequal in length (0.8–1.0 mm) and thickness to one another except 1 of 4 filaments of ventral group much thicker than others when compared basally; all filaments very slightly tapered toward apex and nearly smooth on cuticular surface except 1 of 4 filaments of ventral group markedly tapered from base to basal 1/3 and with well marked annular ridges and furrows along thickened basal portion (common stalk of ventral group and stalk of paired filaments of ventral group also with marked annular ridges and furrows), and densely covered with minute tubercles on cuticular surface. **Abdomen.** Dorsally, all segments nearly transparent though segments 1 and 9 pale yellow; segment 1 with few to several small tubercles submedially near anterior margin and with 1 simple slender short hair-like seta on each side; segment 2 with 1 simple slender short hair-like seta and 5 very short setae on each side; segments 3 and 4 each with 4 hooked spines and 1 very short seta on each side; segment 5 lacking dorsal spine-combs; segments 6–9 each with spine-combs in transverse row together with comb-like groups of minute spines on each side; segment 9 with pair of distinct triangular terminal hooks (Fig. 6D). Ventrally, segment 4 with few simple slender very short setae on each side; segment 5 with pair of bifid hooks submedially and few very short simple slender setae on each side; segments 6 and 7 each with pair of bifid or trifid inner and simple outer hooks somewhat spaced from each other and few very short simple slender setae on each side; segments 4–8 with comb-like groups of minute spines. Each side of segment 9 with 3 grapnel-shaped hooklets. **Cocoon** (Fig. 6E, F). Wall-pocket-shaped, moderately woven; anterior margin not thickly woven; much shortened covering only abdomen of a pupa; floor roughly woven from posterior tip to anterior 1/6; individual threads visible; 1.5–1.7 mm long by 0.8–1.0 mm wide.

**Mature larva.** Body length 4.2 mm. Body whitish, with distinct pattern of color markings as follows: thoracic segment 1 encircled with light reddish-brown transverse band



Fig. 6. Pupa of *Simulium (Gomphostilbia) barioense* sp. nov. A, gill filaments (male pupa, right side and dorsal view); B, basal portion of gill filaments with 2 trichomes below base of gill (male, left side and outer view); C, basal portion of gill filaments (female, right side and outer view); D, terminal hooks (end view); E and F, cocoons (E, dorsal view; F, lateral view). Scale bars. 0.5 mm for E and F; 0.04 mm for A-C; 0.02 mm for D.

though disconnected medially on ventral surface, abdominal segments 4 and 5 each with light reddish-brown small spot on each lateral surface, abdominal segments 7 and 8 light reddish-brown widely on dorsal surface, and abdominal segment 7 with pair of light reddish-brown spots on ventral surface. Cephalic

apotome whitish-yellow; head spots indistinct though anterior and posterior mediolongitudinal spots very faintly positive. Lateral surface of head capsule yellowish except eye-spot region whitish and large area between eye-spot region and posterior margin very slightly darkened. Ventral surface of head cap-

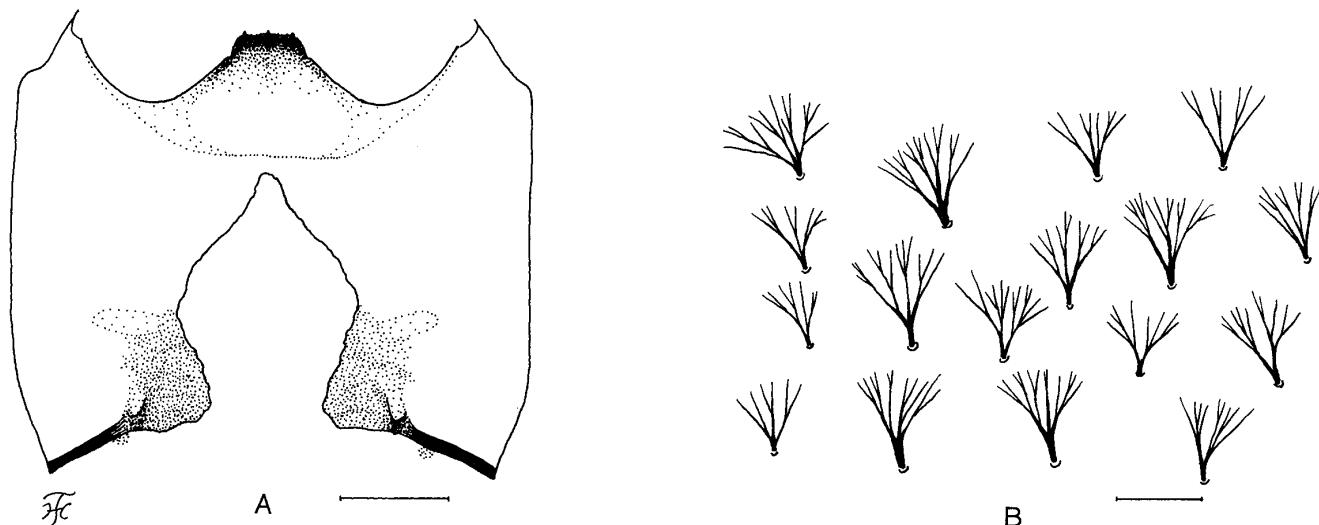


Fig. 7. Mature larva of *Simulium (Gomphostilbia) barioense* sp. nov. A, head capsule showing postgenal cleft (ventral view); B, branched setae on dorsal surface of abdominal segment 8 *in situ*. Scale. 0.1 mm for A; 0.02 mm for B.

sule (Fig. 7A) whitish-yellow; transverse spot on each side of postgenal cleft positive, moderately darkened. Antenna composed of 3 segments and apical sensillum, pale except dorsal surface of 1st segment darkened, somewhat longer than stem of labral fan; proportional lengths of 1st, 2nd, and 3rd segments 1.00:0.94:0.69. Labral fan with 38 main rays. Mandible with 1st comb-tooth much longer than 2nd one, which is as long as or slightly longer than 3rd comb-tooth; mandibular serration composed of 2 teeth (1 medium-sized and 1 small); main tooth at acute angle against mandible on apical side; supernumerary serrations absent. Hypostoma with row of 9 apical teeth; median and each corner tooth prominent, subequal in length to each other, and much longer than 3 intermediate teeth on each side; lateral margin smooth; 4 or 5 hypostomal bristles per side, lying subparallel to lateral margin. Postgenal cleft (Fig. 7A) arrow-head shaped, moderately constricted basally, widest medially, pointed apically, very deep, approaching posterior border of hypostoma. Cervical sclerite composed of 2 small pale rod-like pieces, not fused to occiput, widely separated medially from each other. Thoracic and abdominal cuticle moderately or densely covered with dark branched minute setae each with 4–14 branches (mostly 7–12 branches, Fig. 7B) on dorsal and dorsolateral surface, and also densely covered with simple colorless minute setae on each side of anal sclerite and on each lateral surface near base of rectal papilla.

Rectal scales apparently absent. Rectal papilla compound, each of 3 lobes with 9–12 finger-like secondary lobules. Anal sclerite of usual X-form, with anterior arms slightly longer than posterior ones, broadly sclerotized at base; accessory sclerite absent; basal juncture area with no sensilla. Last abdominal segment expanded ventrolaterally forming double bulges on each side, visible as large conical ventral papilla when viewed from side. Posterior circlet with 80 rows of up to 14 hooklets per row.

**TYPE SPECIMENS.** Holotype female (with associated pupal exuviae and cocoon) reared from pupa, collected from a stream (width 4–6 m, water temperature 18.2°C, shaded, altitude 1,080 m) moderately flowing in a natural forest, near Power Station, Bario Asal, Bario, Sarawak, Malaysia, 2. IX. 2007, by H. Takaoka. Paratypes: 1 female, 2 males (all with associated exuviae and cocoons), 1 pupa (male), 1 mature larva and 2 immature larvae, collected from a trickle (width 10–20 cm, water temperature 21.0°C, exposed to sun, altitude 1,040 m) slowly flowing down to the main channel of a stream mentioned under the holotype, other data as for those of the holotype; 1 pupal exuviae (male), collected from a small stream (width 0.3–1.0 m, water temperature 20.0°C, shaded,

altitude about 1,000 m) flowing in a natural forest near a quarry, near the road from Bario to Pa Ukat, Bario, Sarawak, 1. IX. 2007, by H. Takaoka.

**ECOLOGICAL NOTES.** The pupae and larvae of this new species were collected from grass leaves in water. Associated species were *S. (G.) kelabitense* sp. nov., *S. (G.) lehi*, *S. (G.) paukatense* sp. nov., *S. (G.) sheilae*, *S. (G.)* sp., *S. (S.) keningauense* and *S. (S.)* sp.

**ETYMOLOGY.** The species name *barioense* refers to the name of the locality, Bario, where this new species was collected.

**REMARKS.** According to the key (Takaoka, 2003), *S. (G.) barioense* sp. nov. is readily assigned to the *batoense* species-group within the subgenus *Gomphostilbia* by having the adult antenna with 11 segments, pleural membrane bare, female claw with a large tooth (Fig. 4G), and male hind basitarsus not enlarged (Fig. 5C).

This new species is remarkable in the subgenus *Gomphostilbia* in that it has the pupal gill with 16 filaments in the female (Fig. 6C) and 13 filaments in the male (Fig. 6A, B). The pupal gills of all the other known species have three to ten filaments. It is also striking that this new species has a short cocoon, half the length of the usual form, covering the abdomen only (Fig. 6E, F), similar to those of the *farciminis* species-group of the subgenus *Morops* (Takaoka, 2003).

### *Simulium (Gomphostilbia) paukatense* sp. nov.

**DESCRIPTION. Female.** Body length 1.8–2.1 mm. **Head.** Slightly narrower than width of thorax. Frons (Fig. 8A) brownish-black, shiny, with few dark hairs and few yellow hairs along each lateral margin and few yellow hairs on lower median portion; frontal ratio 1.60–1.77 : 1.00 : 2.44–2.76; frons-head ratio 1.00 : 5.28–5.44. Fronto-ocular area (Fig. 8B)

well developed, narrow, directed dorsolaterally. Clypeus brownish-black, grayish-white pruinose, shiny, moderately covered with dark hairs interspersed with yellow hairs. Labrum 0.64–0.66 times as long as clypeus. Antenna composed of scape, pedicel and 9 flagellomeres, dark brown except scape, pedicel, and little less than basal 1/2 of 1st flagellomere yellow when viewed dorsally (1st flagellomere mostly yellow when viewed ventrally). Maxillary palp composed of 5 segments, light to medium brown, proportional lengths of 3rd, 4th, and 5th segments 1.00 : 1.09 : 1.95–2.15; 3rd segment (Fig. 8C) somewhat swollen; sensory vesicle (Fig. 8C) ellipsoidal, 0.26–0.34 times as long as 3rd segment, with medium-sized opening apically. Maxillary lacinia with 9 or 10 inner and 12–14 outer teeth. Mandible with 22–24 inner and 9–11 outer teeth. Cibarium (Fig. 8D) medially forming sclerotized plate folded forward from posterior margin, with moderately sclerotized medial longitudinal ridge. **Thorax.** Scutum black, markedly shiny, thinly grayish-white pruinose, moderately covered with yellowish-white scale-like recumbent hairs interspersed with dark brown similar hairs. Scutellum brownish-black, covered with yellow and dark brown short hairs and dark brown long upright hairs along posterior margin. Postnotum black, shiny, grayish-white pruinose when viewed at certain angle of light, and bare. Pleural membrane bare. Katepisternum brownish-black, longer than deep, shiny, moderately covered with dark hairs. **Legs.** Foreleg: coxa yellow, somewhat darkened basally; trochanter light brown except base of anterior surface yellow; femur light brown with apical cap medium brown; tibia medium brown with extreme base and large medial portion of outer surface light brown; tibia densely covered with white fine hairs (brightly shiny in light) on most of outer surface; tarsus brownish-black, with moderate dorsal hair crest; basitarsus moderately dilated, 5.44–6.06 times as long as its greatest width. Midleg: coxa light to medium brown except posterior surface brownish-black; trochanter light brown except base much lighter; femur light to medium brown with apical cap medium to dark brown; tibia light to medium brown except base yellow and apical cap dark brown; tibia densely covered with white fine hairs (brightly shiny in light) on most of posterior surface; tarsus light to medium brown

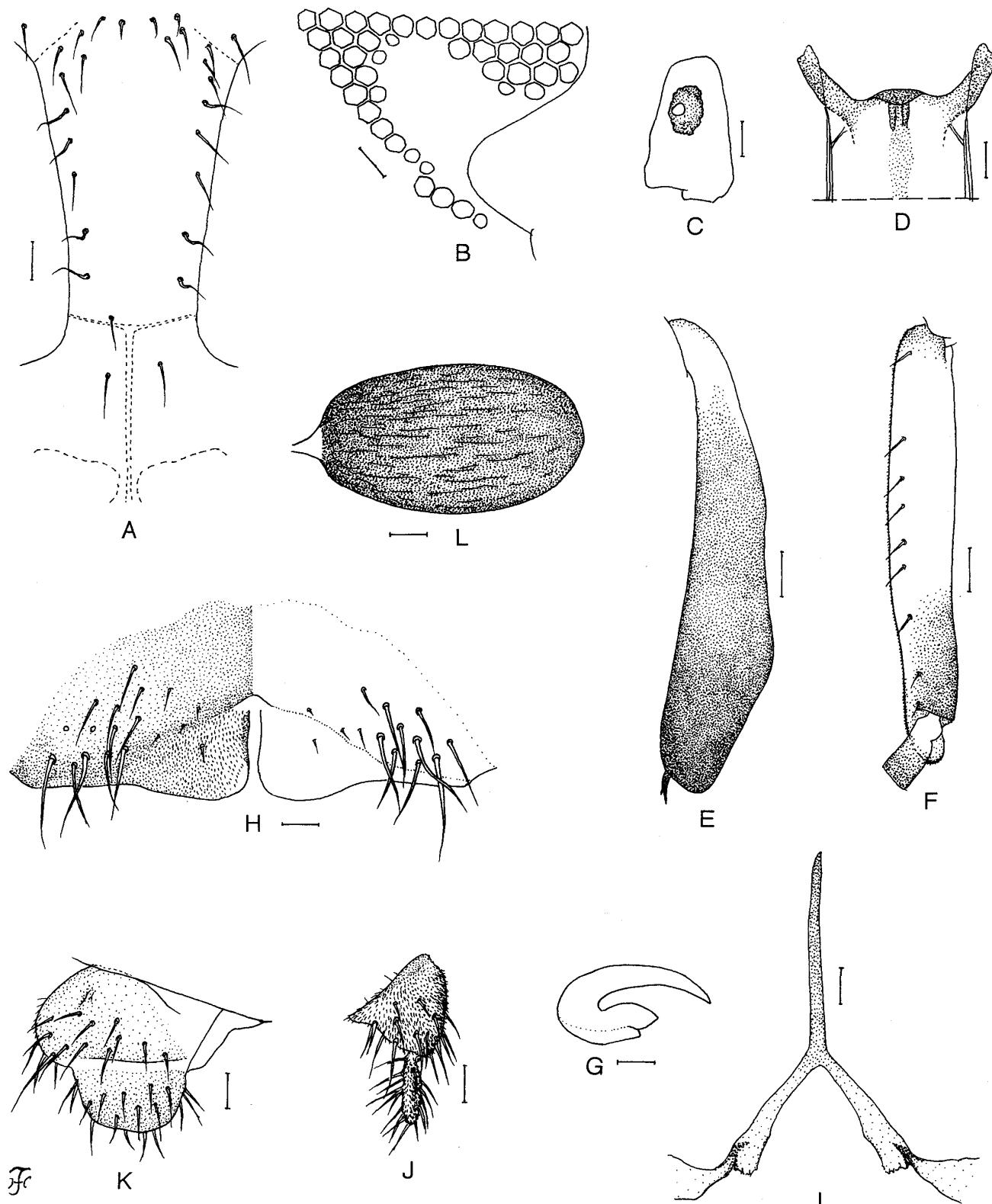


Fig. 8. Female of *Simulium (Gomphostilbia) paukatense* sp. nov. A, frons (frontal view); B, fronto-ocular area (right side); C, 3rd segment of maxillary palp with sensory vesicle (left side and front view); D, cibarium; E, hind tibia (left side and outer view); F, basitarsus and 2nd tarsal segment of hind leg showing calcipala and pedisulcus (left side and outer view); G, claw; H, sternite 8 and ovipositor valves *in situ* (ventral view); I, genital fork (ventral view); J and K, paraprocts and cerci *in situ* (left side; J, ventral view; K, lateral view); L, spermatheca (lateral view). Scale bars. 0.05 mm for E and F; 0.02 mm for A-D and H-L; 0.01 mm for G.

except basal 1/2 or slightly less than basal 1/2 dark yellow. Hind leg: coxa medium brown; trochanter dark yellow; femur medium brown with extreme base dark yellow to light brown and apical cap dark brown to brownish-black; tibia (Fig. 8E) medium brown with base whitish-yellow and apical cap dark brown to brownish-black; tibia densely covered with white fine hairs (brightly shiny in light) on most of outer surface; tarsus (Fig. 8F) dark brown except basal 2/3 of basitarsus (though base medium brown) and basal 1/3 of 2nd tarsal segment yellowish-white; basitarsus narrow, nearly parallel-sided from base to middle, then very slightly narrowed toward apex, 6.30–6.67 times as long as wide, and 0.60–0.64 and 0.51–0.55 times as wide as greatest widths of tibia and femur, respectively; calcipala 1.2 times as long as wide, and 0.52 times as wide as greatest width of basitarsus. Claw (Fig. 8G) with large basal tooth 0.52 times as long as claw. **Wing.** Length 1.5–1.7 mm. Costa with dark spinules and hairs. Subcosta with dark hairs except near apex bare. Hair tuft on stem vein dark brown. Basal portion of radius fully haired;  $R_1$  with dark spinules and hairs;  $R_2$  with hairs only. Basal cell absent. **Abdomen.** Basal scale dark brown, with fringe of whitish-yellow hairs. Dorsal surface of abdomen dark brown to brownish-black except basal 1/2 of segment 2 dark yellow to light brown, moderately covered with dark short to long hairs; tergites of segments 2 and 6–9 wide and shiny, while those of segments 3–5 narrow, nearly quadrate, subequal in shape and size to one another, and all dull; ventral surface of segment 2 entirely pale whitish-yellow, and those of other segments medium to dark brown; sternal plate on segment 7 undeveloped. **Genitalia.** Sternite 8 (Fig. 8H) bare medially, with 10–17 medium-long to long hairs together with few short slender hairs on each side. Ovipositor valves (Fig. 8I) triangular, with round medioposterior corners, thin, membranous, moderately covered with microsetae interspersed with 1 or 2 short setae; inner margins very slightly sinuous, slightly sclerotized, and moderately separated from each other. Genital fork (Fig. 8I) of usual inverted-Y form, with arms of moderate width; arm moderately folded medially. Paraproct in ventral view (Fig. 8J) nearly triangular, pointed medially, and with 3 sensilla on anteromedial surface; paraproct in lateral view (Fig. 8K) somewhat produced ventrally, 0.63 times

as long as wide, with 13–22 short to long hairs on ventral and lateral surfaces. Cercus in lateral view (Fig. 8K) short, rounded posteriorly or subquadrate, 0.56–0.58 times as long as wide. Spermatheca (Fig. 8L) ellipsoidal, 1.70 times as long as its greatest width, well sclerotized except duct and small area near juncture with duct unsclerotized, and with many fissures on surface; internal setae absent; both accessory ducts slender, subequal in diameter to major one.

**Male.** Body length 1.9–2.2 mm. **Head.** Wider than thorax. Upper eye consisting of 17 or 18 vertical columns and 16 or 17 horizontal rows of large facets. Face black, grayish-white pruinose. Clypeus black, moderately covered with dark brown medium-long stout hairs interspersed with several yellow slender hairs on each side of lower margin. Antenna composed of scape, pedicel and 9 flagellomeres, dark brown except scape, pedicel and base of 1st flagellomere yellow; 1st flagellomere elongate, 1.46–1.52 times as long as 2nd flagellomere. Maxillary palp with 5 segments, light brown, proportional lengths of 3rd, 4th, and 5th segments 1.00 : 1.05–1.10 : 2.24–2.41; 3rd segment (Fig. 9A) widened apically; sensory vesicle (Fig. 9A) nearly globular or ellipsoidal, 0.18–0.20 times as long as 3rd segment, and with small opening. **Thorax.** Scutum black, with shiny whitish pruinose spot on each shoulder, which is connected through whitish pruinose band along each lateral margin to large whitish pruinose spot on prescutellar area; scutum moderately covered with light to dark brown (bright copper-colored in light) short hairs interspersed with dark brown longer hairs on prescutellar area; scutellum light brown, with dark brown short hairs and dark brown long upright hairs along posterior margin. Postnotum black, whitish pruinose, shiny when illuminated at certain angle of light, and bare. Pleural membrane bare. Katepisternum brownish-black to black, longer than deep, moderately covered with dark short hairs. **Legs.** Foreleg: coxa yellow, somewhat darkened basally; trochanter light brown except base yellow; femur light brown with apical cap somewhat darker; tibia medium brown with large medial portion of outer surface light brown; tibia densely covered with yellowish-white fine hairs (brightly shiny in light) on most of outer surface; tarsus brownish-black, with moderate dorsal hair crest; basitarsus

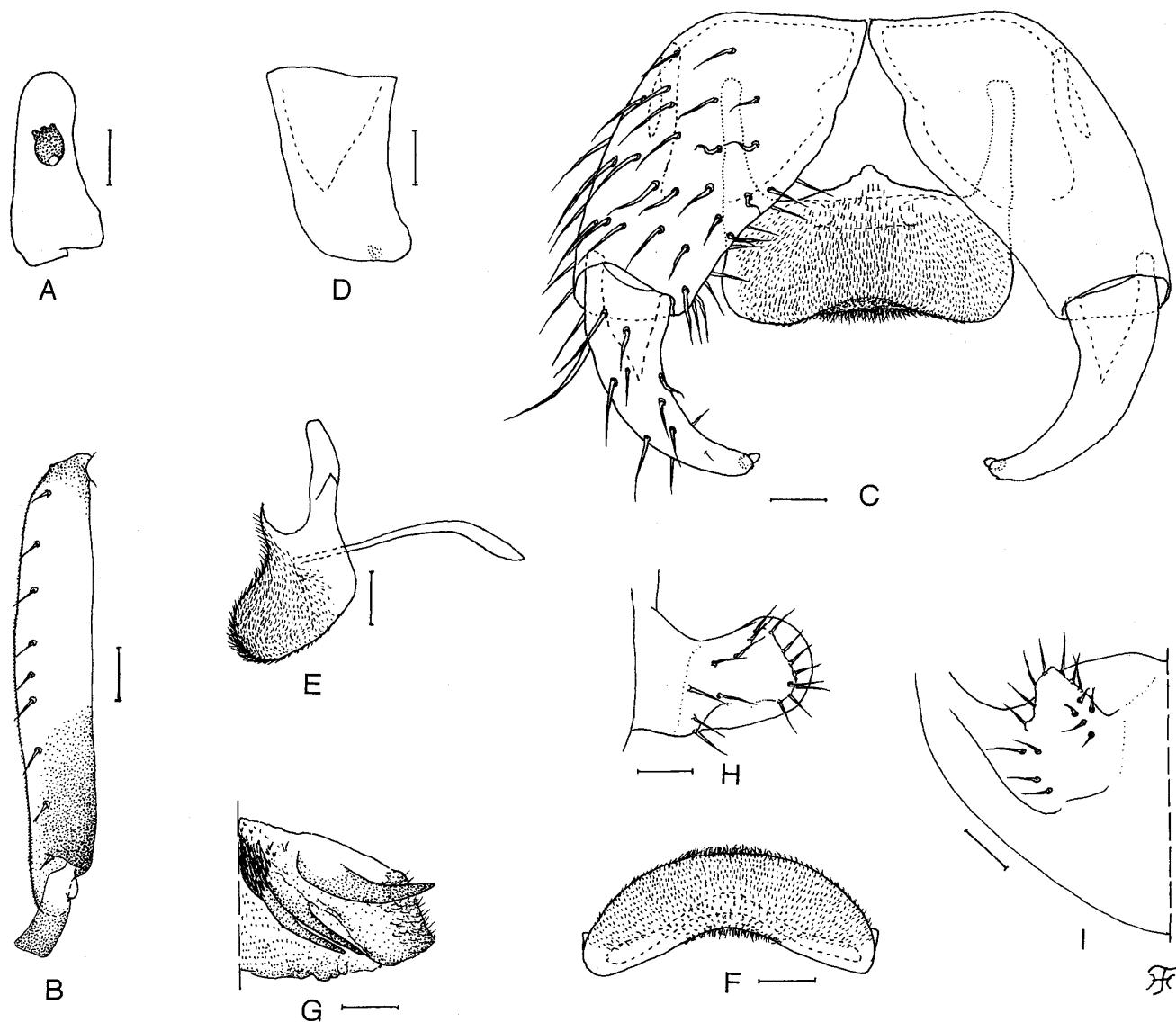


Fig. 9. Male of *Simulium (Gomphostilbia) paukatense* sp. nov. A, 3rd segment of maxillary palp with sensory vesicle (right side and front view); B, basitarsus and 2nd tarsal segment of hind leg showing calcipala and pedisulcus (left side and outer view); C, coxites, styles, ventral plate *in situ* (ventral view); D, style (right side and ventrolateral view); E, ventral plate and median sclerite (lateral view); F, ventral plate (end view); G, paramere and aedeagal membrane with dorsal plate (left side and end view); H and I, 10th abdominal segments and cerci (H, right side and lateral view; I, right side and end view). Scale bars. 0.05 mm for B; 0.02 mm for A and C-I.

moderately dilated, 6.53–6.69 times as long as its greatest width. Midleg: coxa medium brown except posterior surface brownish-black; trochanter medium brown except base light brown; femur medium to dark brown; tibia medium to dark brown except extreme base light brown; tibia densely covered with yellowish-white fine hairs (brightly shiny in light) on posterior surface of basal portion; tarsus medium to dark brown except basal 1/3 light brown. Hind leg: coxa medium brown; trochanter dark yellow to light brown; femur medium brown with extreme base light brown

and apical cap dark brown to brownish-black; tibia medium to dark brown with base light brown and apical cap brownish-black; tarsus (Fig. 9B) medium brown except basal 3/5 of basitarsus (though base medium brown) and basal 1/3 of 2nd tarsal segment yellowish-white; basitarsus narrow, nearly parallel-sided, 5.69–5.91 times as long as wide, and 0.54–0.56 and 0.59–0.61 times as wide as greatest widths of tibia and femur, respectively; calcipala 1.2 times as long as wide, and about half as wide as greatest width of basitarsus. **Wing.** Length 1.5 mm. Other feature as in female except sub-

costa bare. **Abdomen.** Basal scale black, with fringe of light brown hairs. Dorsal surface of abdomen dark brown to brownish-black, moderately covered with dark short to long hairs; segments 2 and 5–7 each with pair of shiny whitish-gray pruinose dorsolateral patches, of which those on segment 2 broadly connected in middle to each other, and those on segments 5–7 disconnected or narrowly connected to each other along anterior margin; in addition, segment 8 shiny on part of each lateral surface when illuminated at certain angle of light. **Genitalia.** Coxite in ventral view (Fig. 9C) nearly rectangular, 1.83–1.96 times as long as its greatest width. Style in ventral view (Fig. 9C) slender, tapered toward apex, 0.77 times as long as coxite, gently bent inward, with apical spine; style in ventrolateral view (Fig. 9D) very slightly narrowed from base to apex, with apex appearing truncate. Ventral plate in ventral view (Fig. 9C) with body transverse, 0.56 times as long as wide, nearly parallel-sided, with anterior margin produced anteromedially, and posterior margin slightly convex medially, and densely covered with microsetae on ventral surface; basal arms of moderate length, nearly parallel-sided; ventral plate in lateral view (Fig. 9E) moderately produced ventrally; ventral plate in end view (Fig. 9F) rounded ventrally, much wider than height and densely covered with microsetae on posterior surface. Median sclerite (Fig. 9C, E) thin, plate-like, wide, and connected to ventral plate far from anterior margin. Paramere (Fig. 9G) of moderate size, moderately covered with fine setae on outer surface near base, with 3 distinct long and stout hooks and several smaller ones close together near apex. Aedeagal membrane (Fig. 9G) moderately setose; dorsal plate (Fig. 9G) weakly sclerotized. Abdominal segment 10 (Fig. 9H, I) without distinct hairs near posterior margin. Cercus (Fig. 9H, I) triangular, encircled with 14–18 hairs.

**Pupa.** Body length 2.0–2.2 mm. **Head.** Integument yellow to light yellowish-brown, moderately covered with small round tubercles on frons and each lateral surface but bare on antennal sheath and on underside of face; antennal sheath without any protuberances; face with pair of simple very long trichomes with uncoiled apices, and frons with 3 pairs of simple very long trichomes with uncoiled apices; 3 frontal trichomes on each side arising close together, subequal in length to one another and

longer than facial one. **Thorax.** Integument yellow to light yellowish-brown, moderately covered with round tubercles, with 3 simple very long trichomes with coiled or uncoiled apices dorsomedially, 2 simple very long trichomes with uncoiled apices anterolaterally, 1 simple medium-long trichome with uncoiled apex posterolaterally, and 3 simple trichomes with uncoiled apices (1 medium-long, 2 short) ventrolaterally on each side. Gill (Fig. 10A, B) composed of 6 slender thread-like filaments, much longer than pupal body, arranged in (2+2)+2 filaments from dorsal to ventral, with somewhat swollen transparent organ ventrally (partially broken) at base; all pairs with long stalk, and dorsal and middle pairs sharing common stalk of moderate length arising from common basal stalk of moderate length; stalks of dorsal and middle pairs together with their common stalk always longer than stalk of ventral pair; stalk of dorsal pair lying against that of lower pair at angle of about 45 degrees when viewed laterally; all filaments light brown, gradually tapered toward apex, subequal in length (2.8–3.5 mm) and thickness to one another; cuticle of all filaments with well marked annular ridges and furrows though becoming less marked apically, densely covered with minute tubercles. **Abdomen.** Nearly as in *S. (G.) kelabitense* sp. nov. except dorsal surface of segments 1 and 2 light yellow, and segment 9 with pair of distinct conical terminal hooks (Fig. 10C). **Cocoon** (Fig. 10D, E). Wall-pocket-shaped, moderately woven, extending ventrolaterally; anterodorsal margin thickly woven, and produced forward as short wide projection; posterior 1/2 with floor moderately woven; individual threads visible; 2.5–3.0 mm long by 1.5–2.0 mm wide.

**Mature larva.** Body length 3.5–4.5 mm. Body whitish-yellow except thorax light grayish-green dorsally and with distinct pattern of color markings as follows: abdominal segments 1 and 4 each encircled with reddish-brown band of moderate width, abdominal segments 2 and 3 each with reddish-brown narrow transverse band on dorsal surface though disconnected medially, abdominal segment 5 with reddish-brown broad transverse band on dorsal and dorsolateral surface, abdominal segments 7 and 8 each with reddish-brown large areas on each dorsolateral surface which are narrowly connected to each other along posterior margin, abdominal segment 6 with small

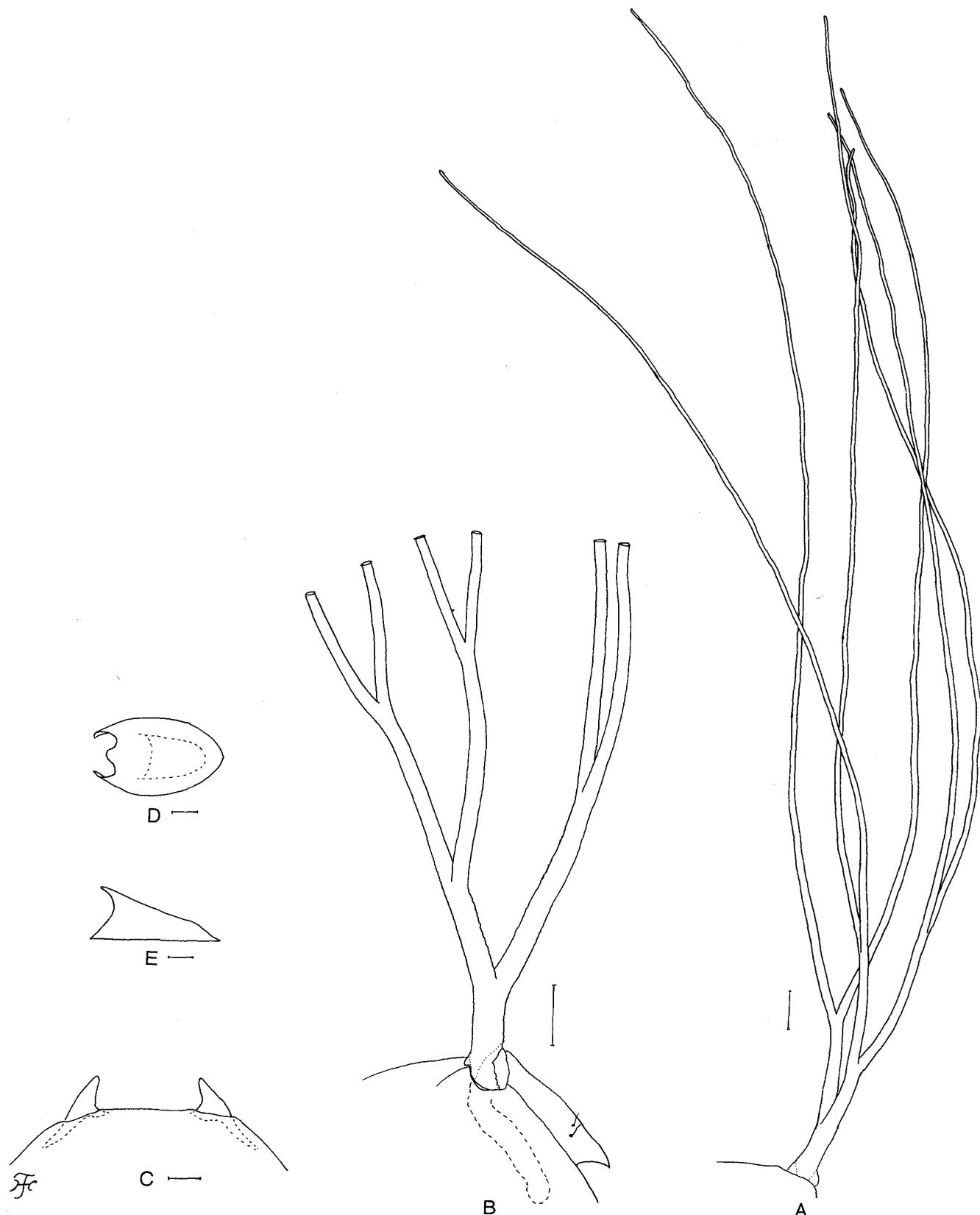


Fig. 10. Pupa of *Simulium (Gomphostilbia) paukatense* sp. nov. A, gill filaments (right side and dorsal view); B, basal portion of gill filaments with 2 trichomes below base of gill (right side and outer view); C, terminal hooks (end view); D and E, cocoons (D, dorsal view; E, lateral view). Scale bars. 0.5 mm for D and E; 0.1 mm for A and B; 0.01 mm for C.

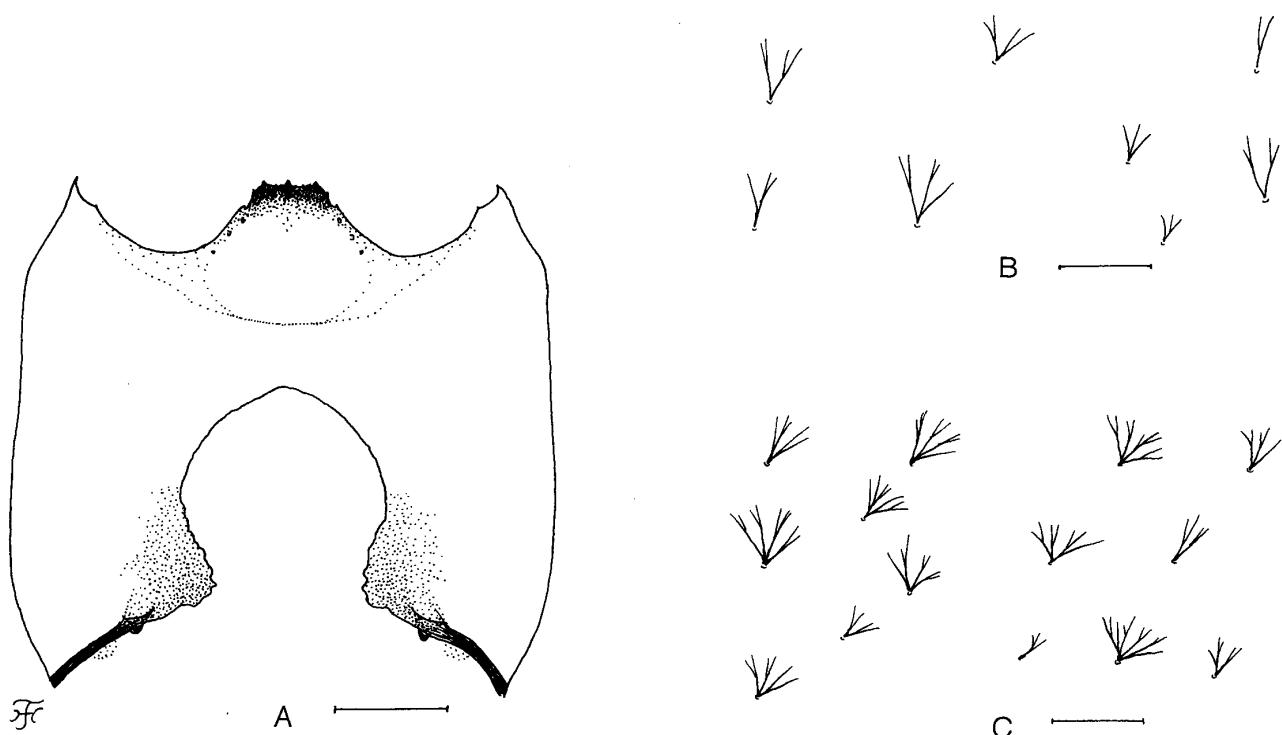


Fig. 11. Mature larva of *Simulium (Gomphostilbia) paukatense* sp. nov. A, head capsule showing postgenal cleft (ventral view); B, branched spinous minute setae on dorsal surface of thoracic segment 1 *in situ*; C, branched minute setae on dorsal surface of abdominal segment 8 *in situ*. Scale. 0.1 mm for A; 0.02 mm for B and C.

reddish-brown transverse band on each lateral surface which is dorsolaterally connected to colored dorsomedial area on abdominal segment 7, and abdominal segment 7 also with reddish-brown transverse band on ventral surface. Cephalic apotome whitish-yellow; head spots indistinct except anterior mediolongitudinal and mediolateral spots very faintly positive. Lateral surface of head capsule whitish-yellow except eye-spot region whitish; eyebrow indistinct. Ventral surface of head capsule (Fig. 11A) whitish-yellow; transverse spot on each side of postgenal cleft indistinct. Antenna composed of 3 segments and apical sensillum, somewhat longer than stem of labral fan; proportional lengths of 1st, 2nd, and 3rd segments 1.00 : 0.65–0.81 : 0.91–0.94. Labral fan with 34–38 main rays. Mandible with 3 comb-teeth decreasing in length from 1st to 3rd; mandibular serration composed of 2 teeth (1 medium-sized and 1 small); major tooth at acute angle against mandible on apical side; supernumerary serrations absent. Hypostoma with row of 9 apical teeth; median and each corner tooth prominent, subequal in length to each other, and much longer than 3 intermediate teeth on each side; lateral margin smooth; 3

or 4 hypostomal bristles per side, lying subparallel to lateral margin. Postgenal cleft (Fig. 11A) moderately constricted basally, widest medially, rounded or somewhat pointed apically, deep, 3.05–5.29 times as long as postgenal bridge. Cervical sclerite composed of 2 small pale rod-like pieces, not fused to occiput, widely separated medially from each other. Thoracic cuticle sparsely or moderately covered with dark branched minute setae each with 2–9 branches (Fig. 11B) and a few dark simple minute setae. Abdominal cuticle sparsely or moderately covered with dark minute branched setae similar to those on thorax on segments 1–4 and moderately or densely covered with dark branched minute setae each with 2–13 branches (mostly 7–10 branches, Fig. 11C) on dorsal and dorsolateral surface of segments 5–9, and also moderately covered with simple colorless minute setae and several dark branched setae with 2–6 branches on each side of anal sclerite of last segment. Rectal scales absent. Rectal papilla compound, each of 3 lobes with 9–13 finger-like secondary lobules. Anal sclerite of usual X-form, with anterior arms slightly shorter than posterior ones, broadly sclerotized at base; accessory

sclerite absent; basal juncture area with no sensilla. Last abdominal segment expanded ventrolaterally forming double bulges on each side, visible as large conical ventral papilla when viewed from side. Posterior circlet with 68–74 rows of up to 15 hooklets per row.

**TYPE SPECIMENS.** Holotype female (with associated pupal exuviae and cocoon) reared from pupa, collected from a small slow-flowing stream (width 30–50 cm, stream bed sand, water temperature 20°C, partially shaded, altitude 1,010 m) in a forest, Pa Ukat, Bario, Sarawak, Malaysia, 3. IX. 2007 by H. Takaoka. Paratypes: 7 females, 4 males (all with associated pupal exuviae and cocoons), same data as those of holotype; 2 females, 4 males (all with associated pupal exuviae and cocoons) and 5 mature larvae, collected from the same stream as noted under the holotype of *S. (G.) kelabitense* sp. nov.

**ECOLOGICAL NOTES.** The pupae and larvae of this species were collected from a broad banana leaf in the water in a slow-flowing small stream. Associated species were *S. (G.) barioense* sp. nov., *S. (G.) kelabitense* sp. nov. and *S. (G.) sheilae*.

**ETYMOLOGY.** The species name *paukatense* refers to the name of the village, Pa Ukat, where this new species was collected.

**REMARKS.** *Simulium (G.) paukatense* sp. nov. is readily assigned to the *batoense* species-group within the subgenus *Gomphostilbia* by having the adult antenna with 11 segments, the pleural membrane bare, the female claw with a large tooth (Fig. 8G) and the male hind basitarsus not enlarged (Fig. 9B).

This new species appears to be very closely related to *S. (G.) sextuplum* Takaoka and Davies described from Peninsular Malaysia (Takaoka and Davies, 1995) in that both species have the female frons almost bare (Fig. 8A), the pupal gill with six filaments (Fig. 10A), and the larval

body with reddish-brown bands. However, this new species is distinguished by the following characteristics (those of *S. (G.) sextuplum* in parentheses): length ratio of the sensory vesicle (Fig. 8C) against the third maxillary palpal segment 0.26–0.34 (0.4), stalks of the dorsal and middle pairs of filaments together with their common stalk much longer than that of the ventral pair (Fig. 10A, B) (subequal or slightly longer), anterodorsal margin of the cocoon much produced forward as a projection (Fig. 10D) (anterodorsal margin of the cocoon bulged but not forming a projection).

The male of this new species is unique among the subgenus *Gomphostilbia* in that the paramere is moderately covered with minute setae on the outer surface of its basal portion (Fig. 9G), a character very rarely occurring in other subgenera [e.g., *S. (Simulium) dumogaense* Takaoka and Roberts and *S. (S.) tumpaense* Takaoka and Roberts from Sulawesi (Takaoka, 2003)].

#### *Simulium (Gomphostilbia) charlesi* sp. nov.

**DESCRIPTION. Female.** Body length 2.4 mm. **Head.** Almost as wide as width of thorax. Frons (Fig. 12A) very narrow, brownish-black, not shiny, moderately covered with yellowish-white scale-like recumbent short hairs interspersed with several dark simple longer hairs along each lateral margin; narrow area just above and between antennal bases densely covered with yellowish-white scale-like hairs; frontal ratio 1.74 : 1.00 : 6.14; frons-head ratio 1.00 : 10.81. Fronto-ocular area (Fig. 12A) well developed, very narrow, directed dorsolaterally. Clypeus brownish-black, not shiny, moderately covered with dark long hairs as well as whitish-yellow scale-like hairs except medial portion of upper 1/2 bare. Labrum 0.53 times as long as clypeus. Antenna (Fig. 12B) composed of scape, pedicel and 7 flagellomeres, whitish-yellow except flagellomeres 5–7 entirely medium brown, flagellomere 3 medium brown on outer and dorsal (or posterior) surface, and flagellomere 1 medium brown on ventral (or anterior) surface of apical 1/4. Maxil-

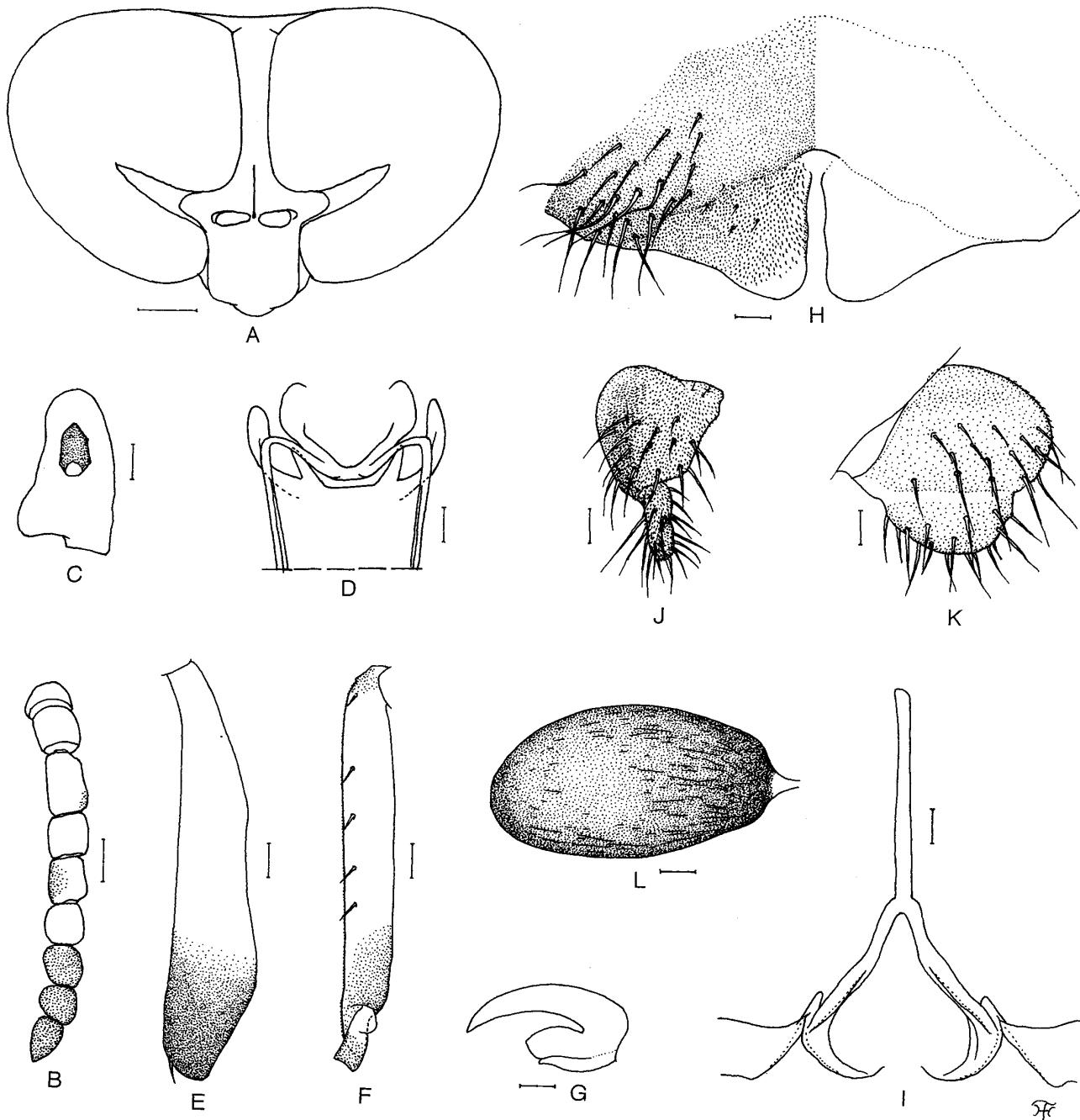


Fig. 12. Female of *Simulium (Gomphostilbia) charlesi* sp. nov. A, head showing narrow frons and fronto-ocular areas (front view); B, antenna (right side and lateral view); C, 3rd segment of maxillary palp with sensory vesicle (left side and front view); D, cibarium; E, hind tibia (left side and outer view); F, basitarsus and 2nd tarsal segment of hind leg showing calcipala and pedisulcus (left side and outer view); G, claw; H, sternite 8 and ovipositor valves *in situ* (ventral view); I, genital fork (ventral view); J and K, paraprocts and cerci *in situ* (right side; J, ventral view; K, lateral view); L, spermatheca (lateral view). Scale bars. 0.1 mm for A; 0.05 mm for B, E and F; 0.02 mm for C, D and H-L; 0.01 mm for G.

lary palp composed of 5 segments, light to medium brown, proportional lengths of 3rd, 4th, and 5th segments 1.00 : 1.11 : 2.63; 3rd segment (Fig. 12C) somewhat swollen; sensory vesicle (Fig. 12C) ellipsoidal, 0.29–0.31 times as long as 3rd segment, with medium-sized opening apically. Maxillary lacinia with 9 or 10

inner and 12 outer teeth. Mandible with 20 inner and 8 or 9 outer teeth. Cibarium (Fig. 12D) with pair of triangular well-sclerotized projections directed dorsolaterally from posterior margin. **Thorax.** Scutum brownish-black (except anterior calli medium brown), shiny, thinly grayish-white pruinose, moderately cov-

ered with yellowish-white scale-like recumbent hairs. Scutellum dark brown, covered with yellowish-white short hairs as well as dark brown short hairs, and dark brown long upright hairs along posterior margin. Postnotum dark brown, slightly shiny, thinly grayish-white pruinose when viewed at certain angle of light, and bare. Pleural membrane bare. Katepisternum dark brown, longer than deep, shiny, moderately covered with yellowish-white fine hairs and dark brown stout hairs. **Legs.** Foreleg: coxa whitish-yellow; trochanter whitish-yellow except posterior surface light brown; femur medium brown with apex narrowly yellowish-white; tibia light to medium brown with extreme base and apex yellowish-white and medial portion of outer surface widely lighter; tarsus brownish-black, with moderate dorsal hair crest; basitarsus moderately dilated, 6.00–6.44 times as long as its greatest width. Midleg: coxa medium brown except posterior surface brownish-black; trochanter yellow except outer surface of apical 1/2 light brown; femur medium brown with apex narrowly whitish-yellow; tibia medium brown except basal 1/3 yellowish-white; tarsus light brown except basal 3/4 to 4/5 of basitarsus, basal 1/3 of 2nd segment and base of 3rd segment yellowish-white. Hind leg: coxa medium brown; trochanter whitish-yellow; femur medium brown with base and apex narrowly whitish-yellow; tibia (Fig. 12E) whitish-yellow except apical 1/4 or little more dark brown; tarsus (Fig. 12F) light to medium brown except basal 3/4 or little more of basitarsus (though base light brown) yellowish-white, basal 1/2 of 2nd tarsal segment, and base of 3rd and 4th segments whitish-yellow; basitarsus narrow, nearly parallel-sided, 6.83–7.36 times as long as wide, and 0.55–0.57 and 0.46–0.48 times as wide as greatest widths of tibia and femur, respectively; calcipala 1.44 times as long as wide, and 0.56 as wide as greatest width of basitarsus. Claw (Fig. 12G) with large basal tooth 0.50 times as long as claw. **Wing.** Length 2.1–2.2 mm. Costa with dark spinules and hairs except basal portion with yellow hairs. Subcosta with dark hairs except near apex bare. Hair tuft on stem vein mostly yellow. Basal portion of radius fully haired; R<sub>1</sub> with dark spinules and hairs; R<sub>2</sub> with hairs only. Basal cell absent. **Abdomen.** Basal scale medium brown, with fringe of whitish-yellow hairs. Dorsal surface

of abdomen light to medium brown except basal 1/2 of segment 2 dark yellow and tergites 3–9 dark brown, moderately covered with dark short to long hairs; tergites of segments 2 and 6–8 wide and shiny, while those of segments 3–5 narrow, nearly quadrate, subequal in shape and size to one another, and all dull; ventral surface of segment 2 entirely dull yellow, and those of other segments light brown except sternite 8 dark brown; sternal plate on segment 7 undeveloped. **Genitalia.** Sternite 8 (Fig. 12H) bare medially, with 16–21 medium-long to long hairs together with a few short slender hairs on each side. Ovipositor valves (Fig. 12H) triangular, with round medioposterior corners, thin, membranous, moderately covered with microsetae interspersed with 1–3 short setae; inner margins very slightly sinuous, slightly sclerotized, and moderately separated from each other. Genital fork (Fig. 12I) of usual inverted-Y form, with narrow stem and arms; each arm strongly folded medially appearing to have projection directed anterodorsally; each arm also with curved projection directed posteromedially. Paraproct in ventral view (Fig. 12J) nearly triangular, with 3 sensilla on anteromedial sclerotized surface; paraproct in lateral view (Fig. 12K) produced ventrally, 0.73 times as long as wide, with 17–19 medium-long to long hairs on ventral and lateral surfaces. Cercus in lateral view (Fig. 12K) short, 0.57 times as long as wide, and rounded posteriorly. Spermatheca (Fig. 12L) ellipsoidal, 1.67–1.79 times as long as its greatest width, well sclerotized (including juncture with duct), and with many fissures on surface; internal setae absent; both accessory ducts slender, nearly as wide as major one.

**Male.** Body length 2.1–2.4 mm. **Head.** Wider than thorax. Upper eye consisting of 11 vertical columns and 12 horizontal rows of large facets. Face dark brown, whitish-gray pruinose. Clypeus dark brown, densely covered with yellow scale-like short to medium-long hairs (mostly directed upwards) interspersed with about 10 dark brown simple longer hairs on each side of lower 1/2. Antenna (Fig. 13A) composed of scape, pedicel and 7 flagellomeres, with color similar to that of female; 1st flagellomere elongate, 1.68 times as long as 2nd flagellomere. Maxillary palp with 5 segments, light brown, proportional lengths of 3rd, 4th, and 5th segments 1.00 : 1.19 : 2.88; 3rd segment (Fig. 13B) somewhat widened apically; sensory

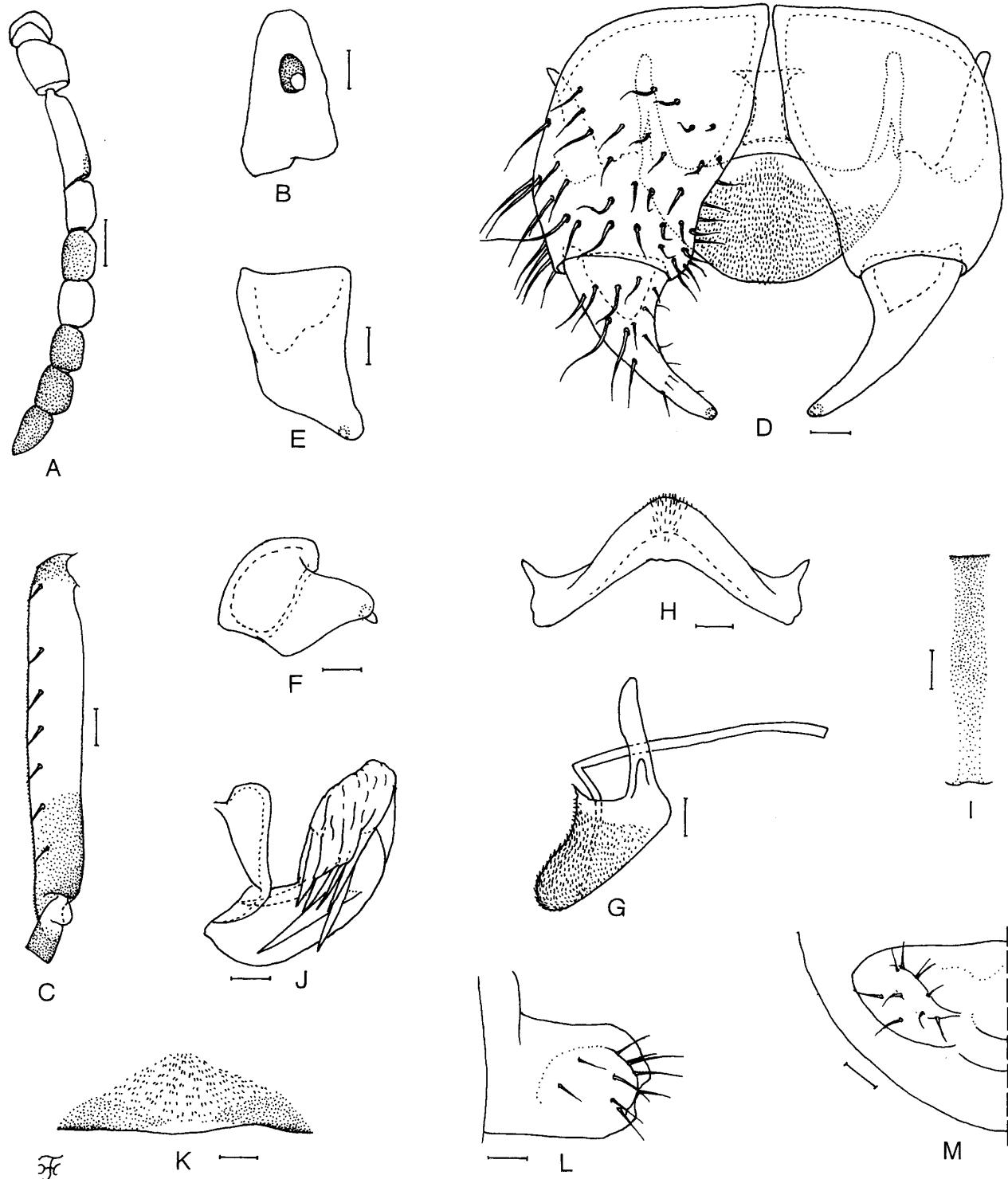


Fig. 13. Male of *Simulium (Gomphostilbia) charlesi* sp. nov. A, antenna (right side and lateral view); B, 3rd segment of maxillary palp with sensory vesicle (right side and front view); C, basitarsus and 2nd tarsal segment of hind leg showing calcipala and pedisulcus (left side and outer view); D, coxites, styles, ventral plate and median sclerite *in situ* (ventral view); E, style (right side and ventrolateral view); F, style (right side and end view); G, ventral plate and median sclerite (lateral view); H, ventral plate (end view); I, median sclerite (front view); J, paramere (left side and dorsal view); K, aedeagal membrane with dorsal plate (end view); L and M, 10th abdominal segments and cerci (L, right side and lateral view; M, right side and end view). Scale bars. 0.05 mm for A and C; 0.02 mm for B and D-M.

vesicle (Fig. 13B) nearly ellipsoidal, 0.26–0.28 times as long as 3rd segment, and with medium-sized opening. **Thorax.** As in female except dense covering of whitish-yellow recumbent hairs. **Legs.** Color nearly as in female except mid tibia and basitarsus whitish-yellow on little less than basal 1/3 and on basal 3/5, respectively. Fore basitarsus moderately dilated, 7.00–7.13 times as long as its greatest width; hind basitarsus (Fig. 13C) narrow, nearly parallel-sided, 6.42–6.64 times as long as wide, and 0.57–0.58 and 0.49–0.50 times as wide as greatest widths of tibia and femur, respectively; calcipala 1.34 as long as its basal width, and 0.50–0.64 times as wide as greatest width of basitarsus. **Wing.** Length 1.8–1.9 mm. As in female except subcosta entirely bare. **Abdomen.** Basal scale medium brown, with fringe of light brown hairs. Dorsal surface of segment 2 yellow (though narrow area along posterior margin slightly darker in 1 male), those of other segments medium brown, moderately covered with dark brown hairs; segments 2 and 5–7 each with pair of shiny whitish-gray pruinose dorsolateral patches, of which those on segment 2 broadly connected in middle to each other, and those on segments 5–7 not connected to each other. **Genitalia.** Coxite in ventral view (Fig. 13D) nearly rectangular, 1.63 times as long as its greatest width. Style in ventral view (Fig. 13D) short, 0.77 times as long as coxite, markedly tapered from base to apex, gently bent inward, with apical spine; style in ventrolateral view (Fig. 13E) wide basally, slightly narrowed from base to apical 1/4, then abruptly tapered toward apex; style in end view (Fig. 13F) with posteroventral margin nearly straight or slightly concave. Ventral plate in ventral view (Fig. 13G) with body transverse, 0.49 times as long as wide, markedly narrowed posteriorly, with anterior margin slightly produced anteromedially and posteroventral margin rounded, and densely covered with microsetae on ventral surface; basal arms of moderate length, slightly diverged; ventral plate in lateral view (Fig. 13H) much produced ventrally; ventral plate in end view (Fig. 13I) rounded ventrally, and sparsely covered with microsetae on medial portion of posterior surface. Median sclerite (Fig. 13G, I) thin, plate-like, narrow, and connected to ventral plate apart from anterior margin. Paramere (Fig. 13J) with body strongly sclerotized, with several distinct long and

stout hooks. Aedeagal membrane (Fig. 13K) moderately setose; dorsal plate (Fig. 13K) weakly sclerotized only near both ends. Abdominal segment 10 (Fig. 13L, M) without distinct hairs near posterior margin on ventral surface. Cercus (Fig. 13L, M) round, encircled with 7–10 hairs.

**Pupa.** Body length 2.8–3.0 mm. **Head.** Integument yellow to yellowish-brown, moderately covered with small round and conical tubercles (Fig. 14A) on frons and area along posterior margin of each lateral surface but bare on antennal sheath, most of lateral surface and underside of face; antennal sheath without any protuberances; face with pair of simple very long trichomes with uncoiled apices, and frons with 3 pairs of simple very long trichomes with uncoiled apices; 3 frontal trichomes on each side arising close together, subequal in length to one another and slightly longer than facial one. **Thorax.** Integument yellow to yellowish-brown, moderately covered with round tubercles, with 3 simple very long trichomes with coiled or uncoiled apices dorsomedially, 2 simple trichomes with uncoiled apices (1 long and 1 very long) anterolaterally, 1 simple long trichome with uncoiled apex posterolaterally, and 3 simple trichomes with uncoiled apices (1 long, 2 medium-long) ventrolaterally on each side. Gill (Fig. 14B) composed of 8 slender thread-like filaments, arranged in  $(1+1+1)+[(1+2)+2]$  or  $(2+1)+[(1+2)+2]$  filaments from dorsal to ventral, with somewhat swollen transparent organ ventrally (partially broken) at base; upper triplet composed of 3 individual filaments (Fig. 14C) or 1 individual and 2 paired filaments (Fig. 14B, D) arising from very short stalk directed upward from short common basal stalk; middle triplet composed of 1 individual and 2 paired filaments with short stalk directed forward and somewhat inward; filaments of dorsal and middle triplet group subequal in length (1.5–2.0 mm long) and thickness to one another, though filaments of middle triplet slightly longer than those of dorsal triplet; inner filament (3.1–3.5 mm long) of ventral pair longest and thickest of all, about 1.3 times as long as outer filament (2.3–2.8 mm long) of same pair, and 1.7–2.0 times as long as 6 other filaments of dorsal and middle triplet groups; stalk of ventral paired filaments very long, much longer than that of middle triplet, and directed forward; middle triplet and ventral pair always sharing very short stalk; stalk

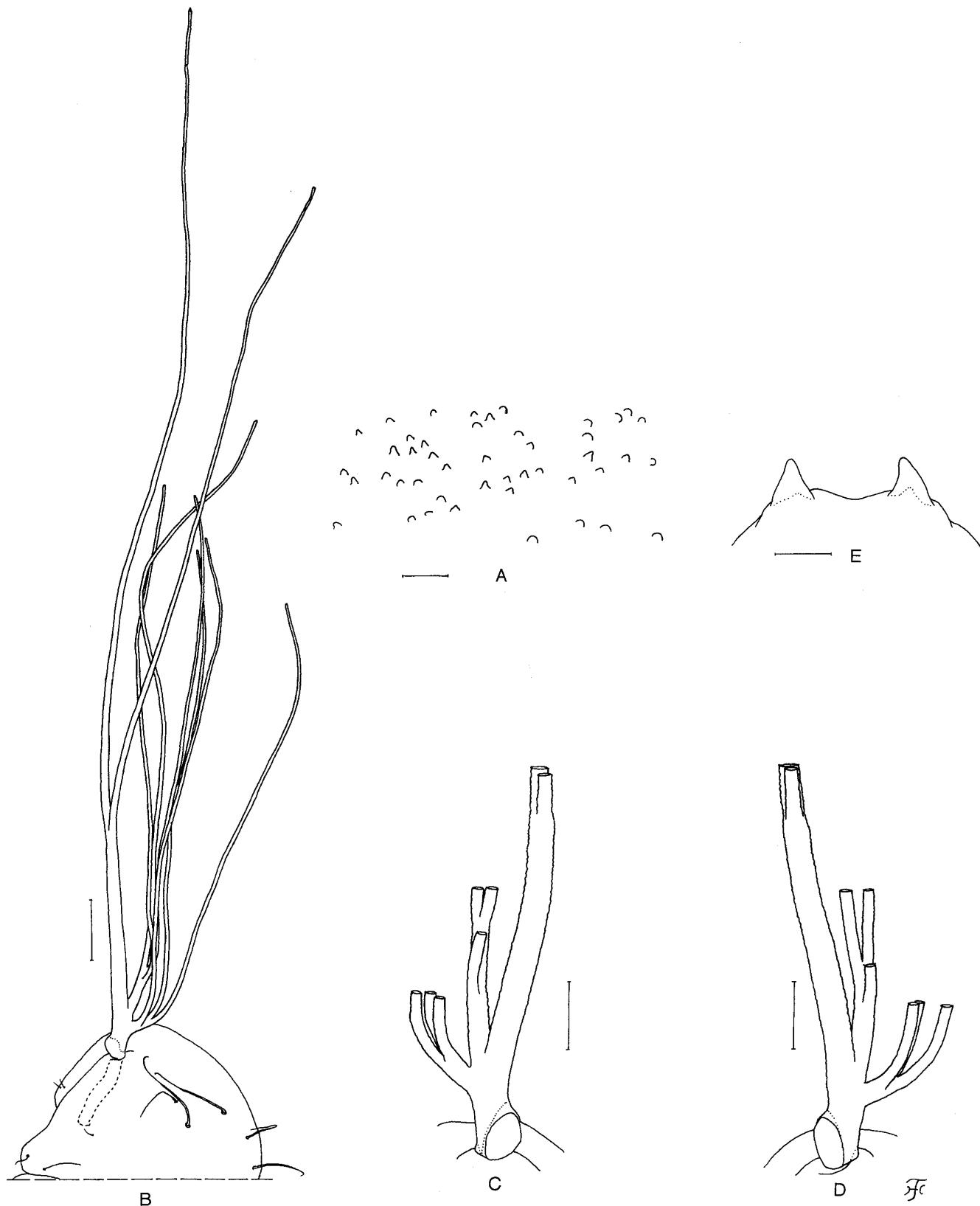


Fig. 14. Pupa of *Simulium (Gomphostilbia) charlesi* sp. nov. A, round and conical tubercles on frons; B, gill filaments (left side and outer view); C and D, basal portion of gill filaments (C, right side and outer view; D, left side and outer view); E, terminal hooks (end view). Scale bars. 0.2 mm for B; 0.1 mm for C and D; 0.01 mm for A and E.

of upper triplet lying against that of lower pair at angle of 70–80 degrees when viewed laterally; all filaments light brown, gradually tapered toward apex; cuticle of all filaments with well-marked annular ridges and furrows though becoming less marked apically, densely covered with minute tubercles. **Abdomen.** Nearly as in *S. (G.) kelabitense* sp. nov. except paired hooks on ventral surface of segment 5 and inner hooks of ventral surface of segments 6 and 7 bifid or trifid or quadrifid, and pair of terminal hooks conical (Fig. 14E). **Cocoon.** Wall-pocket-shaped, moderately woven, extending ventrolaterally; anterodorsal margin somewhat thickly woven; posterior 1/2 with floor moderately woven; individual threads visible; 3.0–3.2 mm long by 1.2–2.0 mm wide.

**Mature larva.** Body length 4.2 mm. Body whitish-yellow except abdominal segments 1–

4 light greyish-green; thoracic segments 2 and 3 and abdominal segments 1–5 each with pair of small conical dorsolateral protuberances (Fig. 15A). Cephalic apotome whitish-yellow; head spots very faintly positive. Lateral surface of head capsule whitish-yellow except eye-spot region whitish; eyebrow indistinct. Ventral surface of head capsule (Fig. 15B) whitish-yellow; transverse spot on each side of postgenal cleft indistinct. Antenna composed of 3 segments and apical sensillum, all pale, somewhat longer than stem of labral fan; proportional lengths of 1st, 2nd, and 3rd segments 1.00 : 0.89 : 0.96. Labral fan with 26 main rays. Mandible with 3 comb-teeth decreasing in length from 1st to 3rd; mandibular serration composed of 2 teeth (1 medium-sized and 1 small); major tooth at acute angle against mandible on apical side; supernumerary serrations

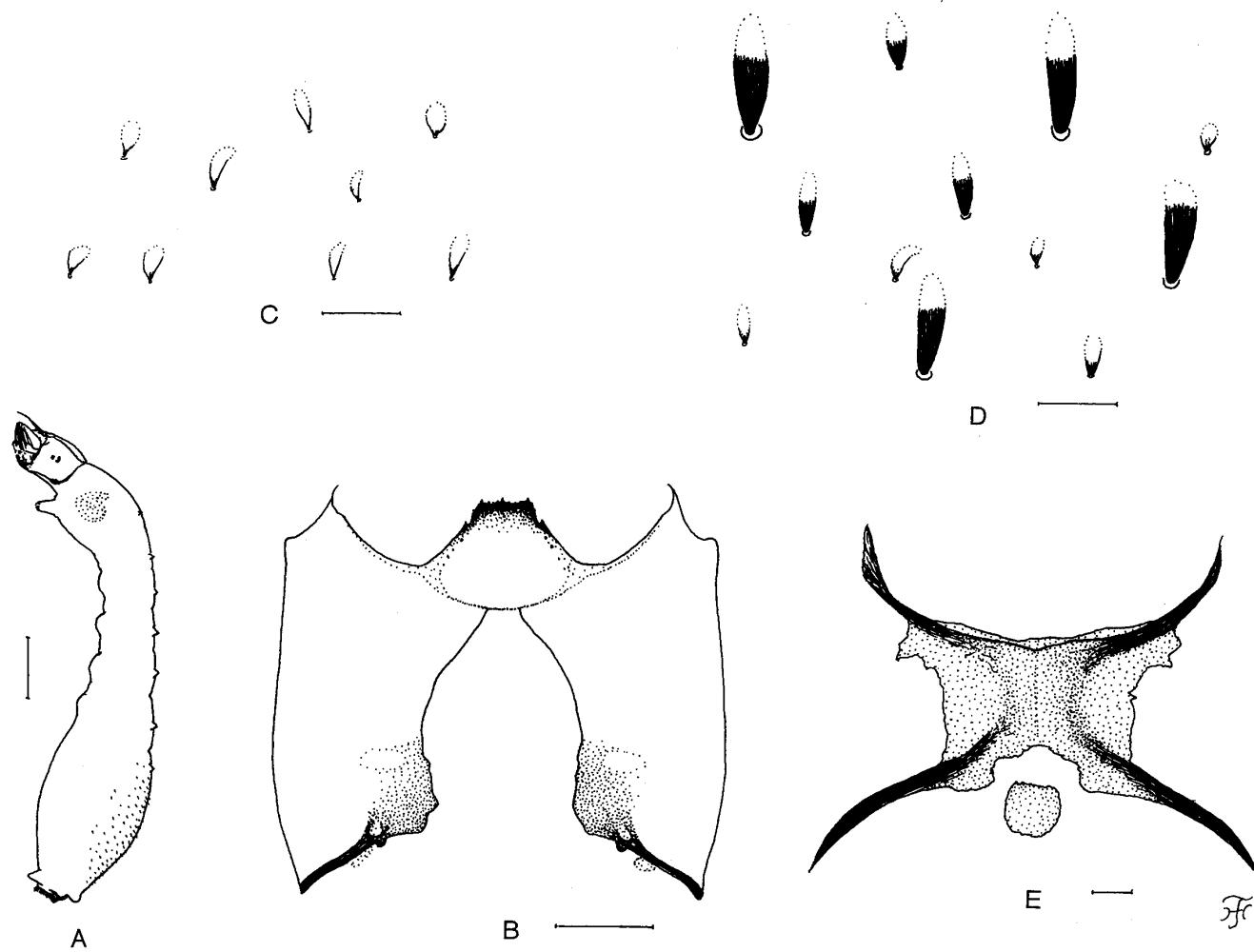


Fig. 15. Mature larva of *Simulium (Gomphostilbia) charlesi* sp. nov. A, whole body showing dorsolateral protuberances on thorax and abdomen (lateral view); B, head capsule showing postgenal cleft (ventral view); C, minute setae on dorsal surface of thoracic segment 1 *in situ*; D, scale-like setae of three different sizes on dorsal surface of abdominal segment 8 *in situ*; E, anal sclerite with additional sclerotized plate (posteroventral view). Scale bars. 0.5 mm for A; 0.1 mm for B; 0.02 mm for C–E.

absent. Hypostoma with row of 9 apical teeth; median and each corner tooth prominent, sub-equal in length to each other, and much longer than 3 intermediate teeth on each side; lateral margin mostly smooth; 4 hypostomal bristles per side, lying parallel to lateral margin. Postgenal cleft (Fig. 15B) moderately constricted basally, widest medially, very deep, reaching posterior border of hypostoma. Cervical sclerite composed of 2 pale small slender rod-like pieces, not fused to occiput, widely separated medially from each other. Thoracic cuticle moderately covered with very minute flat scale-like setae (Fig. 15C) on dorsal surface. Abdominal cuticle moderately covered with very minute flat setae (similar to those on thorax) dorsally on segments 1–4 and moderately covered with very minute to minute flat scale-like setae of 3 different sizes (i.e., smallest setae similar to those on thorax, 2 larger types of setae darkened and stout on basal 1/2 and transparent, membranous and often bent posteriorly on apical 1/2, thus making difficult to observe the exact shape of apical portion) (Fig. 15D) on dorsal and dorsolateral surface of segments 5–8, and also moderately covered with simple colorless minute setae interspersed with very minute flat setae (similar to those on thorax) on each side of anal sclerite of last segment. Rectal scales absent. Rectal papilla compound, each of 3 lobes with about 10 finger-like secondary lobules (exact number not countable since the papilla was inside the body). Anal sclerite (Fig. 15E) of usual X-form, with anterior arms nearly as long as posterior ones, broadly sclerotized at base; accessory sclerite absent though small weakly sclerotized plate present medially just posterior to anal sclerite; basal juncture area with no sensilla. Last abdominal segment expanded ventrolaterally forming double bulges on each side, visible as large conical ventral papilla when viewed from side. Posterior circlet with 72 rows of up to 11 hooklets per row.

**TYPE SPECIMENS.** Holotype female (with associated pupal exuviae and cocoon) reared from pupa (preserved in 80% ethanol), collected from a moderately flowing stream (width 8–10 m, depth 0.5–1.0 m, water temperature 21.6°C, exposed to sun, altitude about 1,000 m) crossing the road from Bario to Pa Umur, Bario,

Sarawak, Malaysia, 5. IX. 2007, by H. Takaoka. Paratypes: 1 female, 3 males (all reared from pupae), 2 pupal exuviae, 1 mature larva and 2 immature larvae, same data as those of the holotype.

**ECOLOGICAL NOTES.** The pupae and larvae of this new species were collected from bamboo leaves trailing in the water. Associated species was *S. (S.) keningauense*.

**ETYMOLOGY.** The species name *charlesi* is in honor of Dr. Charles Leh M. U., Sarawak Museum, Kuching, Sarawak, who kindly arranged the field surveys in Kelabit Highlands.

**REMARKS.** According to the key (Takaoka, 2003), *S. (G.) charlesi* sp. nov. is readily assigned to the *varicorne* species-group within the subgenus *Gomphostilbia* by having the adult antenna with nine segments (Figs. 12B and 13A).

This new species appears to be very closely related to *S. (G.) novemarticulatum* Takaoka and Davies described from female adults collected from Peninsular Malaysia (Takaoka and Davies, 1995) in that both species have nine antennal segments. However, *S. (G.) charlesi* sp. nov. is readily distinguished by the arrangement of the pupal gill, i.e. the inner filament of the ventral pair is much longer and thicker than the outer filament of the same pair (Fig. 14B) (the ventral pair of *S. (G.) novemarticulatum* is composed of two filaments of equal length and thickness according to pupal specimens collected from Peninsular Malaysia—unpublished data).

### *Simulium (Gomphostilbia) parahiyangum* Takaoka and Sigit

*Simulium (Gomphostilbia) parahiyangum* Takaoka and Sigit, 1992: 135–142.

**SPECIMEN EXAMINED.** 1 mature larva, collected from a river (width 10–15

m, depth 0.3–0.5 m, water temperature 19.0°C, shaded, altitude about 1,000 m) moderately flowing in a natural forest, Pa Ukat, Bario, Sarawak, Malaysia, 5. IX. 2007 by H. Takaoka.

**ECOLOGICAL NOTES.** Only one mature larva of this species was collected from a leaf of grass in water. Associated species were *S. (S.) keningauense* and *S. (S.)* sp.

**DISTRIBUTION.** Java, Peninsular Malaysia, Sabah, Sarawak (**New record**), Sumatra and Thailand.

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